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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 642

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. ▼ April 30, 1918

THE FOUR ESSENTIAL FACTORS IN THE PRODUCTION OF MILK OF LOW BACTERIAL CONTENT

By

S. HENRY AYERS, LEE B. COOK, and PAUL W. CLEMMER
of the Dairy Division

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

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FACTORS INFLUENCING THE SANITARY QUALITY OF MILK.

The production of milk of a high sanitary quality involves a knowledge of the influence of numerous factors. Whether these factors are all grouped under one head and considered as a single unit or are grouped into several units, each directly connected with a separate phase of the production of sanitary milk, may not at first thought be of any importance.

Consideration of that point, however, must lead to the view that to deal intelligently with the factors which influence the sanitary quality of milk they must be grouped in such way as to bring together those which are of importance in connection with a definite phase of production. As an example, the question of abundant light

[1] The authors acknowledge their indebtedness to T. E. Woodward, of the Dairy Division; also to W. R. Hale and W. F. Turner, formerly of this division, who made the work possible through their supervision of the experimental barn. They also extend their thanks to the dairy farmers near Grove City, Pa., and to R. R. Welch, of this division, who assisted in making a practical demonstration of the work.

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may be mentioned. It has long been recognized that an abundance of light is necessary for the production of high-grade milk, but that factor must first be placed under a certain group of factors before it can be adjudged correctly. Depending upon whether it bears a direct relation to the bacterial content of milk or exerts a marked influence on the health and comfort of the cattle, it should be grouped accordingly.

In view of these facts, the following group of factors have been selected as a means of clarifying the subject:

1. Factors concerned in the production of milk which is practically free from visible dirt and which has a low bacterial content.
2. Factors most directly concerned in the prevention of the infection of milk with pathogenic organisms.
3. Factors of importance in connection with the health of the cattle.
4. Factors concerned in providing and maintaining conditions suitable for the production of a food product, even though they may not directly affect the quality of the product.

It is realized that some factors may enter into more than one of the groups above, but their greatest importance can generally be assigned to one definite group. For example, the sterilization of utensils is of primary importance in the production of milk of low bacterial content, but it is also a measure in the prevention of infection with pathogenic organisms.

This paper considers only the factors in group 1; that is, those concerned in the production of milk practically free from visible dirt and of low bacterial content.

It is not to be questioned that milk of low bacterial content may be produced under conditions in which every possible factor is controlled, but it is reasonable to suppose that, relatively speaking, some factors may be of more importance than others. It may be possible, therefore, on the average farm, to produce milk of low bacterial content by the combination of a certain few factors which affect the quality of milk more than others. Some of the factors have been extensively investigated, and the results of much excellent work pertaining to the subject have been published. Such work, however, has dealt largely with the value of one factor or with the comparative importance of two or more factors. In our work the problem has been studied from a somewhat different angle.

The endeavor has been to determine methods for the production of milk of low bacterial content in the barn of the ordinary type. The experimental work was confined to a study of conditions which affect the bacterial content of milk sufficiently to be measured. While it is realized that many conditions under which milk is produced may affect its quality from a sanitary or economic standpoint, no attempt was made to study them unless they could be measured in terms of the bacterial count.

OBJECTS OF THE INVESTIGATION.

The objects of the investigation may be outlined as follows:

1. To work on only fresh milk at the time of milking, in order to eliminate the factor of bacterial growth.
2. To obtain conditions as bad as possible in an experimental barn in order to improve them and also to determine the number of bacteria in fresh, dirty milk.
3. To introduce one factor of improvement at a time, so as eventually to obtain milk of low bacterial content.
4. To return to the dirty conditions and then again produce low-count milk by the application of the necessary factors with the object of checking the value of the factors previously determined.
5. To show the relative importance of the selected factors.
6. To use a combination of the essential factors in a practical manner on farms in order to determine their value when used by the average farmer.
7. To show the growth of bacteria in various grades of milk (graded from a bacterial standpoint) when held for different periods of time at various temperatures.

Since the term "production of milk" is usually considered to cover the entire period in which it is in the farmer's hands, the bacterial content during production, as used in that sense, must be considered from two distinct standpoints, first, the bacteria introduced through contamination, and second, their growth in the milk.

In this paper, however, we shall consider the term "production of milk" to cover only the period from the time the milk leaves the cow until it is in the delivery cans or bottles, which includes the time the milk is subject to the usual sources of contamination. The time the milk is held on the farm will be considered as an entirely different phase of production, since the bacterial content during that period is not usually influenced by contamination, but is subject to increase through bacterial growth.

Particular attention is called to the fact that extreme conditions of filth were used merely to emphasize the importance of certain factors. No legitimate excuse can be conceived for the production of milk from dirty cattle or in a filthy stable.

DESCRIPTION OF BARN AND METHODS USED IN THE PRODUCTION OF THE MILK.

For the experiments a small barn was constructed at the Dairy Division farm at Beltsville, Md., a view of which is shown as figure 1. The building provided space for four cows and was of wooden construction throughout, including floor, gutter, and mangers. The walls were left in the rough; that is, with exposed beams, etc. The loft above the cows was constructed of narrow boards laid from 1 to 2 inches apart on crossbeams. From the loft hay was thrown down and the cows fed just before milking. The stable had two doors and two windows; the latter were small and provided only 2

square feet of light for each cow. Five hundred cubic feet of air space was provided for each cow. An untrained milker, wearing ordinary work clothes and giving no special attention to the cleanliness of his hands, was employed to milk and take care of the cows.

During the work the cows were alternated from time to time in order to equalize any unusual results due to the individual animal. For example, in working with the small-top and open pails two cows were milked first into the open pail and a few days later were milked into the small-top pail.

In all the work the milk was poured unstrained into cans in the barn. The small-top pail used in the experiments was the type with

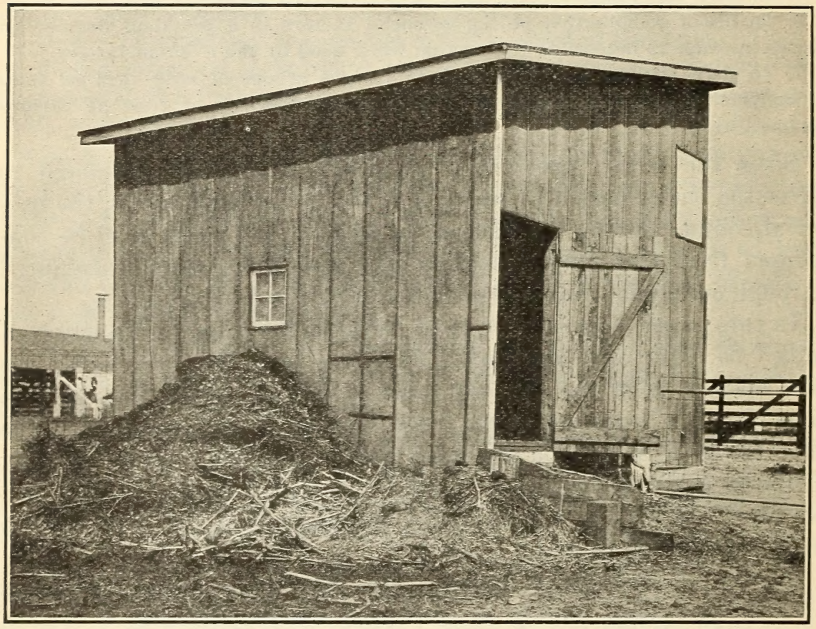


FIG. 1.—Experimental barn used in this investigation.

a hood or cover on an ordinary pail, as shown in figure 2. Utensils were sterilized by being placed in a sterilizer, steamed for 30 minutes, and afterwards allowed to remain there until used. When the utensils were not sterilized they were merely washed clean and inverted in the milk house. Covers were not placed on the cans, and the utensils were left in that position until time to milk.

Sterile utensils in the strict sense of the term means their absolute freedom from living organisms. When the statement is made that utensils were sterilized it means that they were free from all bacteria which are destroyed by flowing steam at 100° C. (212° F.). There are, of course, a few spores which are resistant to flowing steam and which can be destroyed only by steam of high temperature under pressure.

METHOD OF SAMPLING AND MAKING THE BACTERIAL COUNT.

After milking, the cans of milk were promptly carried from the barn to the milk room, a distance of a few hundred feet, situated in the same building as the laboratory. Long-handled white-agate dippers, cleaned between milkings and sterilized just before using, were used to stir the milk and to take the sample. A separate dipper was used for each sample, and the milk was poured carefully into sterile pint bottles, which were immediately closed with sterile caps. The fact that the laboratory was in the same building made it possible to pour the plates within one hour after milking. The same routine was followed at both morning and evening milkings, regardless of how the other factors varied. Since the interpretation of results depends partly on the nature of the medium and on its subsequent incubation it is necessary to state exactly how the counts were obtained. For the sake of uniformity plain-extract agar, prepared according to the revised recommendations of the Committee on Standard Methods of Bacterial Milk Analysis,[1] was used. The plates were incubated for five days at 30° C. (86° F.) and counted with the aid of a hand glass of three and one-half diameters magnification.

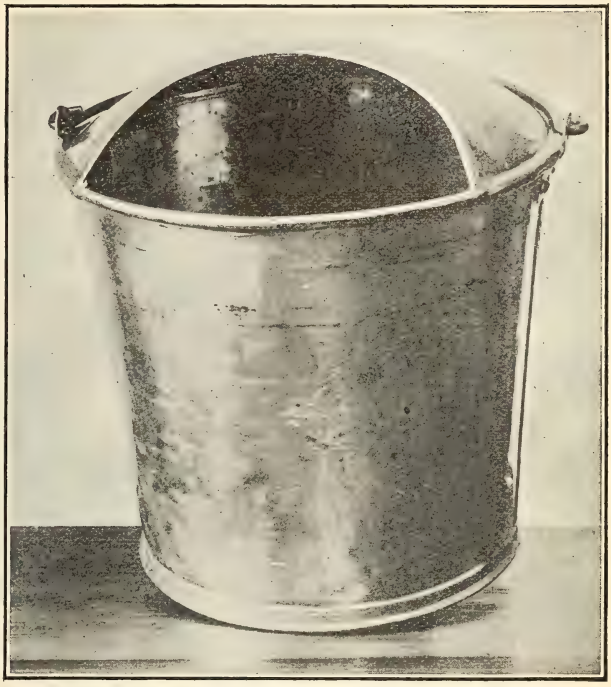


FIG. 2.—The small-top pail used in the experiments.

THE EXPERIMENTAL WORK.

In the experiments the plan was to begin with conditions in which the barn and cows were as filthy as possible. When those conditions

[1] Rochester meeting of American Public Health Association, September, 1915 (Committee on Standard Methods).

were obtained it was the intention, by the gradual elimination of certain factors which contribute to the contamination of milk, to produce milk that was practically free from visible dirt and had a low bacterial content. Following that, the next step was to duplicate the conditions in order to determine again the value of the essential factors. To show clearly the scope of the work and the conditions under which the milk was produced, the experiments are listed in the order in which they were conducted:

Experiment No.	Period covered.	Conditions.
1.	July 22, to August 14, 1915	Cows and floor were dirty and the manure was removed weekly. The utensils were not sterilized.
2.	September 14 to October 7, 1915	Cows and floor were dirty and the manure was removed weekly. The utensils were sterilized.
3.	November 10 to 24, 1915	Cows and floor were dirty and the manure was removed twice a week. Udders and teats of the cows were washed and the utensils were sterilized.
4.	February 27 to April 10, 1916	Cows were clean and bedded, floor was clean, and the manure was removed daily. Udders and teats of the cows were washed; also of two others not washed. The utensils were sterilized.
5.	April 11 to May 6, 1916	Cows and floor were dirty and the manure was removed weekly. The utensils were sterilized.
6.	May 8 to 31, 1916	Cows and floor were dirty and the manure was removed weekly. The utensils were not sterilized.
7.	June 5 to 13, 1916	Cows and floor were clean and the manure was removed daily. Udders and teats of the cows were washed and the utensils were sterilized.

During the dates not covered by the periods above the cows were kept in the barn and the relative value of the factors was studied by other methods. The general conditions of the barn as previously described, method of feeding, etc., were not changed during the experiments. The results obtained in the various experiments above outlined will be described in their proper order.

EXPERIMENT NO. 1 (COWS AND FLOOR DIRTY, MANURE REMOVED WEEKLY, UTENSILS NOT STERILIZED).

The first condition of the barn was one of extreme filth. Four cows were placed there on January 28, 1915, and the first experiment was begun on July 22 of that year. In the intervening period no atten-

tion was given to the stable except to remove manure. Dust was allowed to accumulate in the barn; consequently at the beginning of the first experiment its condition was little if any better than that of the average low-grade barn. During the experiment, which extended from July 22 to August 14, the manure was removed once a week; as a result varying quantities of filth were present on the floor and on the cows. A picture of the barn just before the weekly removal of the manure is shown in figure 3. It will be noted that the gutter was filled with manure and the floor almost entirely covered. Figure 4 shows one of the cows at that time. It will be seen that

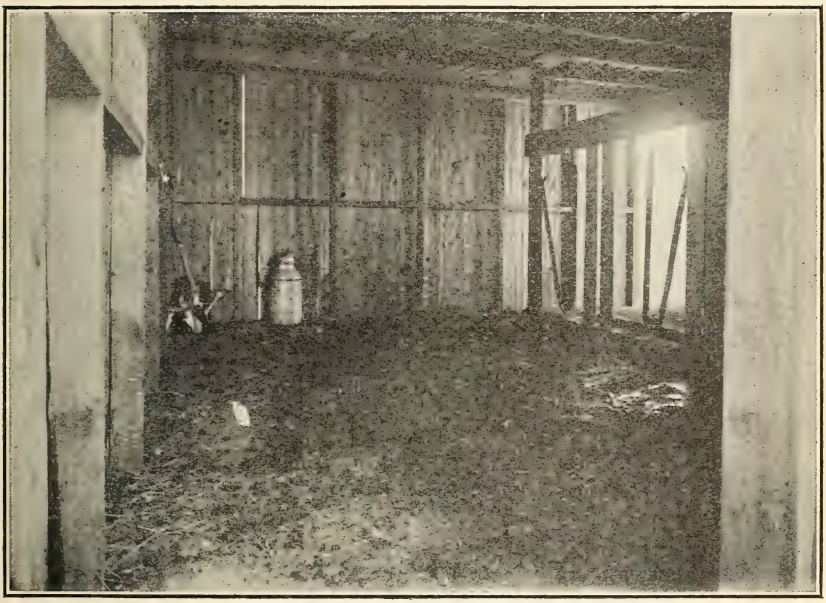


FIG. 3.—Condition of barn during Experiment No. 1.

the flanks, udder, and teats of the cow were almost entirely covered with manure. The general type of milker employed throughout the experiments may also be seen in the picture. Under such barn conditions and with unsterilized utensils it seemed probable that the bacterial counts obtained would be as high as those from any other dirty barn. It is not intended to intimate that conditions in the average barn in this country are as bad as these, but, as stated, for the purposes of the experiment it was desired to have the worst possible conditions.

Two cows were milked into open and the other two into small-top pails, which were washed clean but not sterilized. The milk was then poured into clean, unsterilized cans in the barn, after which it was carried to the milk house, where samples were taken immediately both night and morning.

At each milking a sample was taken from the open pail and one from the small-top pail. In this connection it must be understood that the sample came from a can, but that the open or small-top pail was used in the milking.

Table 1 shows the bacterial analyses of 32 samples of milk. The numbers represent milkings, both in the table and throughout the bulletin. It will be seen from the table that the first count of milk from the open pail was 14,000 bacteria per cubic centimeter. As the manure accumulated on the floor during the first week and the cows became more dirty the bacterial content of the milk increased. The

FIG. 4.—Condition of one of the cows during Experiment No. 1.

highest count obtained with the open pail was 1,200,000 and with the small-top pail 750,000 bacteria per cubic centimeter. Throughout the experiment the counts from the open pail were higher than the corresponding counts from the small-top pail. The difference is represented fairly well by the average count of the 32 samples from the open pail, which was 497,653 bacteria per cubic centimeter, as compared with 368,214 for the small-top pail.

It must be remembered, however, that the actual value of the small-top pail can not be determined accurately from these results for the reason that the utensils were not sterilized, which brings in an unknown factor, since the number of bacteria introduced into the milk from the unsterilized utensils is variable. The figures show that the use of the small-top pail was of some value, even when none of the utensils were sterilized.

TABLE 1.—*Bacteria per cubic centimeter in dual samples of fresh milk produced under conditions described in Experiment No. 1.*

Date.	Sample No.	Open pail.	Small-top pail.	Date.	Sample No.	Open pail.	Small-top pail.
1915.				1915.			
July 22, p. m.	1	14,000	.....	Aug. 5, a. m.	18	600,000	600,000
July 23, a. m.	2	170,000	45,000	Aug. 5, p. m.	19	650,000	550,000
July 23, p. m.	3	125,000	60,000	Aug. 6, p. m.	20	400,000	.....
July 24, a. m.	4	280,000	150,000	Aug. 7, a. m.	21	300,000	250,000
July 26, p. m.	5	600,000	450,000	Aug. 9, a. m.	22	.....	400,000
July 27, a. m.	6	.....	200,000	Aug. 9, p. m.	23	550,000	500,000
July 27, p. m.	7	240,000	130,000	Aug. 10, a. m.	24	.....	500,000
July 28, a. m.	8	350,000	160,000	Aug. 10, p. m.	25	350,000	450,000
July 28, p. m.	9	390,000	175,000	Aug. 11, a. m.	26	400,000	300,000
July 29, a. m.	10	320,000	200,000	Aug. 11, p. m.	27	900,000	450,000
July 29, p. m.	11	500,000	340,000	Aug. 12, a. m.	28	1,200,000	500,000
July 30, a. m.	12	900,000	750,000	Aug. 12, p. m.	29	800,000	400,000
July 31, a. m.	13	.....	350,000	Aug. 13, a. m.	30	600,000	450,000
Aug. 3, a. m.	14	.....	750,000	Aug. 13, p. m.	31	450,000	300,000
Aug. 3, p. m.	15	550,000	.....	Aug. 14, a. m.	32	700,000	500,000
Aug. 4, a. m.	16	.....	400,000				
Aug. 4, p. m.	17	600,000	.....	Average.	.....	497,653	368,214

Perhaps the most interesting point brought out by the results was the relatively low bacterial count obtained in all samples. It is reasonable to suppose that milk produced under such extremely filthy conditions would contain millions of bacteria per cubic centimeter. The figures indicate very clearly, however, that large numbers of bacteria are not commonly found in fresh milk. Even when extremely high counts are obtained, they are probably attributable to some other factor, such as growth or subsequent infection during the various stages of handling. Throughout the experiments the milk was examined before cooling, as it was the intention to avoid the variable factor of contamination from unsterilized coolers.

EXPERIMENT NO. 2 (COWS AND FLOOR DIRTY, MANURE REMOVED WEEKLY, UTENSILS STERILIZED).

Having determined the number of bacteria in fresh milk produced under extreme conditions of filth, where unsterilized utensils were used, the next step was to use one factor which was considered of utmost importance in preventing contamination, namely, sterilized utensils. Samples of milk were taken from September 14 to October 7, 1915, under conditions as nearly identical as possible with those of the previous experiment, with the exception that the cans and pails were sterilized.

By the use of sterilized utensils a remarkable decrease in the bacterial content of the milk was found. From the results of 36 samples shown in Table 2 it will be seen that the average count of milk from open pails was 22,677 bacteria per cubic centimeter, compared with 17,027 from small-top pails. Comparison with the results shown in Table 1 is convincing proof of the value of sterilized utensils. It should be remembered that the figures represent samples taken under filthy conditions and that the only factor contributing to the difference in the bacterial count was the use of sterilized utensils.

The range in the bacterial content of samples taken from the open pail during the experiment was from 2,500 to 80,000, and in the sam-

ples from the small-top pail from 2,100 to 60,000 per cubic centimeter. It is quite remarkable that the counts were not higher on account of the dirty condition of cows and barn floor.

TABLE 2.—*Bacteria per cubic centimeter in dual samples of fresh milk produced under conditions described in Experiment No. 2.*

Date.	Sample No.	Open pail.	Small-top pail.	Date.	Sample No.	Open pail.	Small-top pail.
1915.				1915.			
Sept. 14, a. m.	1	20,000	9,000	Sept. 25, p. m.	20	5,000	2,500
Sept. 15, a. m.	2	40,000	20,000	Sept. 27, a. m.	21	55,000	30,000
Sept. 15, p. m.	3	25,000	11,000	Sept. 27, p. m.	22	12,000	9,000
Sept. 16, a. m.	4	13,000	16,000	Sept. 28, a. m.	23	36,000	21,000
Sept. 16, p. m.	5	10,000	3,500	Sept. 28, p. m.	24	4,100	3,400
Sept. 17, a. m.	6	12,000	23,000	Sept. 29, a. m.	25	25,000	60,000
Sept. 17, p. m.	7	5,600	2,400	Sept. 30, a. m.	26	14,000	12,000
Sept. 18, a. m.	8	10,500	45,000	Sept. 30, p. m.	27	9,000	12,000
Sept. 20, a. m.	9	75,000	35,000	Oct. 1, a. m.	28	11,000	9,000
Sept. 20, p. m.	10	4,500	3,200	Oct. 1, p. m.	29	65,000	20,000
Sept. 21, a. m.	11	32,000	24,000	Oct. 2, a. m.	30	80,000	60,000
Sept. 21, p. m.	12	5,600	2,500	Oct. 4, a. m.	31	40,000	55,000
Sept. 22, a. m.	13	7,500	3,800	Oct. 5, a. m.	32	18,000	9,000
Sept. 22, p. m.	14	14,500	2,600	Oct. 5, p. m.	33	15,000	5,500
Sept. 23, a. m.	15	16,000	12,500	Oct. 6, a. m.	34	60,000	45,000
Sept. 23, p. m.	16	2,500	2,800	Oct. 6, p. m.	35	25,000	13,000
Sept. 24, a. m.	17	18,000	14,000	Oct. 7, a. m.	36	8,500	7,000
Sept. 24, p. m.	18	5,600	2,100				
Sept. 25, a. m.	19	16,500	7,200	Average.		22,677	17,027

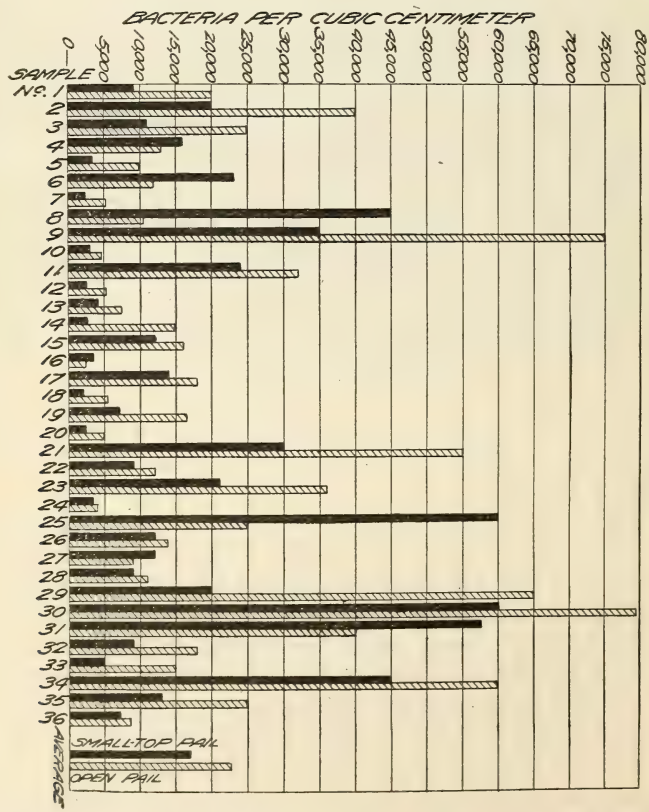


FIG. 5.—Bacterial content of milk from sterilized open and small-top pails during Experiment No. 2.

From the results it is possible to determine something of the value of the small-top as compared with that of the open pail. The average of the bacterial counts of milk from the small-top pail as given in Table 2 was about 5,500 bacteria per cubic centimeter lower than that of milk from the corresponding open pail. The true value of the small-top pail, however, is more definitely shown in figure 5, in which the bacterial count of each sample of milk is shown and plotted in columns. The comparative heights indicate the difference in the number of bacteria per cubic centimeter in milk from open and small-top pails at the same milking. In 29 of the 36 samples the bacterial count of milk from the open pail was higher than that from the small-top. The results confirm the conclusions of previous investigators as to the value of the small-top pail.

EXPERIMENT NO. 3. (COWS AND FLOOR DIRTY, MANURE REMOVED TWICE A WEEK, UDDERS AND TEATS OF THE COWS WASHED, UTENSILS STERILIZED).

In Experiment No. 2 the use of sterilized utensils, as has been shown, resulted in a remarkable lowering of the bacterial count. In Experiment No. 3, where sterilized utensils were used, a second factor was introduced, which consisted in washing the udders and teats of the cows.

The condition of the barn, as shown in figure 6, was the same as in the previous experiments except that the manure was removed twice

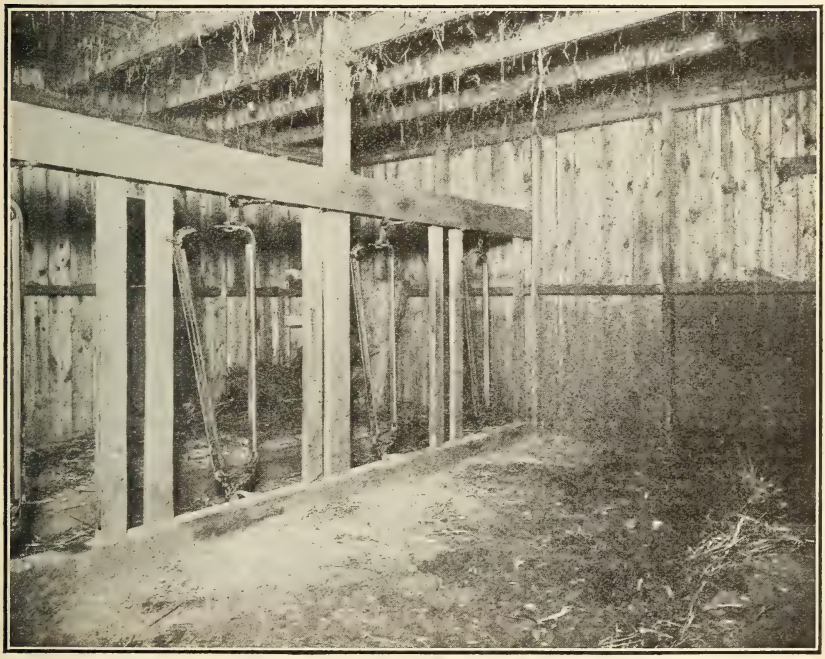


FIG. 6.—Condition of barn during Experiment No. 3.

a week. It will be noticed that the walls and ceiling were extremely dirty. Hay protruded through the open ceiling, and the gutter was completely filled with manure which was scattered over the floor toward the stanchions.

The condition of the cows is well illustrated by figure 7. Their flanks were caked with manure, but the visible dirt was removed from the udders, which were washed before each milking. After having been thoroughly washed with clean water and a cloth they were wiped with another clean, damp cloth rinsed in clean water. The flanks of the cows, which were liable to be rubbed by the milker's arm, also were kept clean.

During the period from November 10 to 24, 1915, 18 samples of milk were examined from the open and 23 samples from the small-top pail. The results in Table 3 show that the average number of bacteria in milk from the open pail was 6,166 bacteria per cubic centimeter, compared with 2,886 from the small-top pail.

In the experiment 12 samples of milk were drawn directly from the udder into sterile tubes at about the middle of the milking. The average count of the milk from the four cows was 987 bacteria per cubic centimeter. The difference between that average and the average in the milk from the open pail is 5,179, which represents the number of bacteria per cubic centimeter introduced through external contamination. The average number of bacteria per cubic centimeter of 23 samples from the small-top pail was 2,886; subtracting 987 from the count, the remainder, 1,889 bacteria per cubic centimeter, represents the number added through external contamination.

TABLE 3.—*Bacteria per cubic centimeter in dual samples of fresh milk produced under conditions described in Experiment No. 3.*

Date.	Sample No.	Open pail.	Small-top pail.	Date.	Sample No.	Open pail.	Small-top pail.
1915.				1915.			
Nov. 10, p. m.	1	3,500	2,400	Nov. 19, p. m.	16	.....	4,500
Nov. 11, a. m.	2	38,000	3,100	Nov. 20, a. m.	17	3,600	4,300
Nov. 11, p. m.	3	1,700	2,400	Nov. 20, p. m.	18	.....	1,900
Nov. 12, a. m.	4	2,100	4,300	Nov. 22, a. m.	19	5,600	2,600
Nov. 12, p. m.	5	11,200	1,500	Nov. 22, p. m.	20	.....	5,000
Nov. 13, a. m.	6	4,300	1,800	Nov. 23, a. m.	21	8,500	4,100
Nov. 13, p. m.	7	2,800	1,000	Nov. 23, p. m.	22	.....	2,700
Nov. 15, p. m.	8	5,100	2,900	Nov. 24, a. m.	23	2,800	4,000
Nov. 16, a. m.	9	2,600	2,700				
Nov. 16, p. m.	10	.....	1,200	Average of milk samples	.....	6,166	2,886
Nov. 17, a. m.	11	3,200	2,700				
Nov. 17, p. m.	12	1,700	2,800	Average of 12 udder samples.	.....	987	987
Nov. 18, a. m.	13	4,600	2,100				
Nov. 18, p. m.	14	3,500	2,000				
Nov. 19, a. m.	15	6,200	3,800	Difference	.....	5,179	1,899

The results show that when the udders were washed clean and the small-top, sterilized pail is used it is possible to produce milk of a bacterial count closely corresponding to the number found in milk

drawn directly from the udder. In all cases in which the bacteria in milk as it left the udder were counted the figures were low, because the results represented milk drawn in the middle of milking. It is, of course, well known that the "foremilk" contains more bacteria per cubic centimeter than the "middle milk." The difference between the bacterial count of the "regular milk" and of milk drawn directly from the udder ("middle milk") is designated as external contamination. As the foremilk is included in the regular milk this difference is probably greater than it should be.

The figures show also the value of the small-top pail. The difference, however, is not fairly represented by the average, for the reason that two samples of milk from the open pail were much higher than the others, which raised the average.

The most striking fact brought out by the experiment is that milk of a low bacterial count can be obtained, even under filthy conditions, if careful attention is given to three simple factors, namely, sterilized utensils, small-top pails, and clean udders and teats.

Attention is called to the fact that the experiment was conducted under filthy conditions in order to emphasize the value of the three factors mentioned. Common decency alone should not permit the production of milk under such conditions.

FIG. 7.—Condition of one of the cows during Experiment No. 3.

EXPERIMENT NO. 4 (COWS CLEANED AND BEDDED, FLOOR CLEAN, MANURE REMOVED DAILY, UDDERS AND TEATS OF TWO COWS WASHED AND OF TWO OTHERS NOT WASHED, UTENSILS STERILIZED).

The results obtained in previous experiments show that it was possible to obtain milk of a low bacterial count from dirty cows in a dirty stable. Under such conditions it is absolutely necessary to keep the udders and teats of the cows clean, but when the barn floor is covered with manure it is very difficult to do so. To attempt to produce low-count milk under conditions previously described would certainly show poor judgment on the part of the dairyman. It would be unreasonable, therefore, to attempt to keep the udder and teats of the cow absolutely clean when the animal is lying in manure a part of the day. The reasonable way to lessen the work of keeping the cows clean is to remove the manure at least once a day and to keep the floor clean. To keep the cows clean is a matter of economy as well as of common decency.

As may be noted in figure 8, the conditions of the walls and ceiling of the barn were the same as in previous experiments. Straw was used for bedding and the floors and gutter were practically free from manure. A picture of one of the cows also is shown in figure 9. The cows during this experiment were cleaned daily with currycomb and brush, and very little effort was required to keep them free from visible dirt.

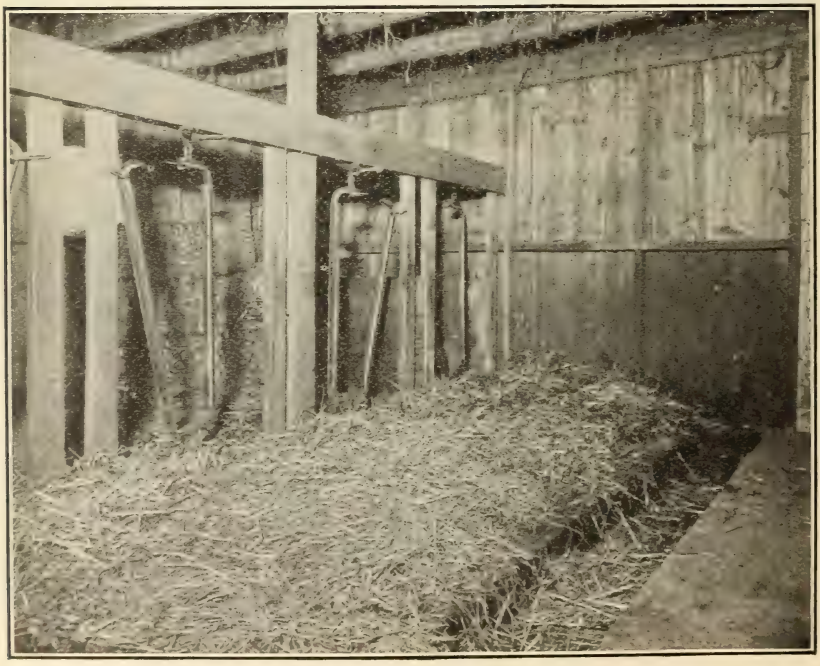


FIG. 8.—Condition of barn during Experiment No. 4.

FIG. 9.—Condition of one of the cows during Experiment No. 4.

During the experiment, which was continued from February 28 to April 10, 1916, the udders and teats of two cows were washed just before milking and the other two were not washed. When the udders were washed clean water and a cloth were used, and they were then wiped with another clean cloth rinsed in clean water. Small-top pails were used throughout the experiment, and the utensils were sterilized.

The results of the bacteriological examination of the milk produced under these conditions are given in Table 4. The average bacterial count of milk when the udders and teats were washed was 2,154 per cubic centimeter, and 4,524 when they were not washed. The average counts show relatively little difference from a bacteriological standpoint so far as the quality of the milk is concerned. An examination of the table, however, shows that there is more uniformity of counts when the udder was washed than when unwashed. The samples from the washed udders ranged from 620 to 5,400, while those from the unwashed udders ranged from 1,090 to 20,000 bacteria per cubic centimeter. The results indicate that under the conditions it is possible to produce milk with a very low bacterial count without washing the udders. If it is desired, however, to produce milk of a uniformly low count when fresh, it is advisable to wash the udders.

TABLE 4.—*Bacteria per cubic centimeter in dual samples of fresh milk produced under conditions as described in Experiment No. 4.*

Date.	Sample No.	Udder and teats.		Date.	Sample No.	Udder and teats.	
		Washed.	Not washed.			Washed.	Not washed.
1916.				1916.			
Feb. 28, p. m.	1	1,600	1,800	Mar. 23, p. m.	37	810	2,660
Feb. 29, a. m.	2	3,700	9,900	Mar. 24, a. m.	38	1,350	4,800
Feb. 29, p. m.	3	5,400	3,600	Mar. 24, p. m.	39	1,360	2,970
Mar. 1, a. m.	4	2,200	6,500	Mar. 25, a. m.	40	2,410	4,010
Mar. 1, p. m.	5	4,600	6,300	Mar. 26, p. m.	41	1,350	4,200
Mar. 2, a. m.	6	3,300	4,700	Mar. 27, a. m.	42	2,740	4,750
Mar. 2, p. m.	7	1,130	2,250	Mar. 27, p. m.	43	1,530	6,700
Mar. 3, a. m.	8	2,270	5,300	Mar. 28, p. m.	44	2,900	3,600
Mar. 3, p. m.	9	1,900	3,100	Mar. 29, a. m.	45	2,300	3,200
Mar. 4, a. m.	10	2,700	6,600	Mar. 29, p. m.	46	2,600	5,100
Mar. 5, p. m.	11	980	1,520	Mar. 30, a. m.	47	3,900	3,500
Mar. 9, a. m.	12	3,900	13,300	Mar. 30, p. m.	48	1,800	3,300
Mar. 9, p. m.	13	2,500	5,100	Mar. 31, a. m.	49	4,200	6,900
Mar. 10, a. m.	14	1,400	20,400	Mar. 31, p. m.	50	1,500	4,100
Mar. 10, p. m.	15	1,370	1,200	Apr. 1, a. m.	51	4,700	3,400
Mar. 11, a. m.	16	1,150	2,370	Apr. 3, a. m.	52	1,600	7,400
Mar. 12, p. m.	17	830	1,050	Apr. 3, p. m.	53	2,300	4,100
Mar. 13, a. m.	18	1,480	2,210	Apr. 4, a. m.	54	3,400	4,700
Mar. 13, p. m.	19	620	1,120	Apr. 4, p. m.	55	1,400	5,500
Mar. 14, a. m.	20	3,600	8,700	Apr. 5, a. m.	56	2,200	5,300
Mar. 14, p. m.	21	910	1,590	Apr. 5, p. m.	57	1,900	2,200
Mar. 15, a. m.	22	1,920	2,350	Apr. 6, a. m.	58	2,900	7,300
Mar. 15, p. m.	23	820	2,670	Apr. 6, p. m.	59	800	5,200
Mar. 16, a. m.	24	2,550	14,800	Apr. 7, a. m.	60	1,400	3,300
Mar. 16, p. m.	25	1,140	1,090	Apr. 7, p. m.	61	2,700	1,500
Mar. 17, a. m.	26	2,190	2,110	Apr. 8, a. m.	62	3,400	9,400
Mar. 17, p. m.	27	1,970	2,680	Apr. 9, p. m.	63	3,200	2,300
Mar. 18, a. m.	28	1,360	2,040	Apr. 10, a. m.	64	2,100	3,900
Mar. 19, p. m.	29	1,520	1,510	Apr. 10, p. m.	65	2,400	7,200
Mar. 20, a. m.	30	820	3,070				
Mar. 20, p. m.	31	680	2,390	Average of milk samples		2,154	4,524
Mar. 21, a. m.	32	2,190	3,410				
Mar. 21, p. m.	33	1,660	3,240	Average of udder samples		739	757
Mar. 22, a. m.	34	2,070	6,020				
Mar. 22, p. m.	35	1,140	2,480				
Mar. 23, a. m.	36	2,290	3,110	Differences		1,415	3,767

The interpretation of the average counts obtained from washed and unwashed udders must receive special attention. The counts as they stand show 2,154 bacteria per cubic centimeter from cows with washed udders and 4,524 bacteria from those with unwashed udders. It can be said that washing the udder reduced the bacterial counts about 50 per cent, which agrees in a general way with the results obtained by Stocking.[1] This assertion should not be made, however, without taking into consideration the actual bacterial content of the milk. When the number of bacteria is small a 50 per cent reduction indicates practically no difference in the quality of the milk, as, for example, a count of 2,000 per cubic centimeter compared with 1,000. If, however, the counts were as high as 1,000,000 and 500,000, respectively, in the two samples, the factor causing the difference would still produce a 50 per cent reduction, but there would be a much greater difference in the quality of the milk with the higher counts.

The bacterial counts of the 65 samples in this experiment have been plotted and are shown in figure 10, which brings out in a striking manner the fact that milk from the washed udders has

[1] See list of references at end of bulletin.

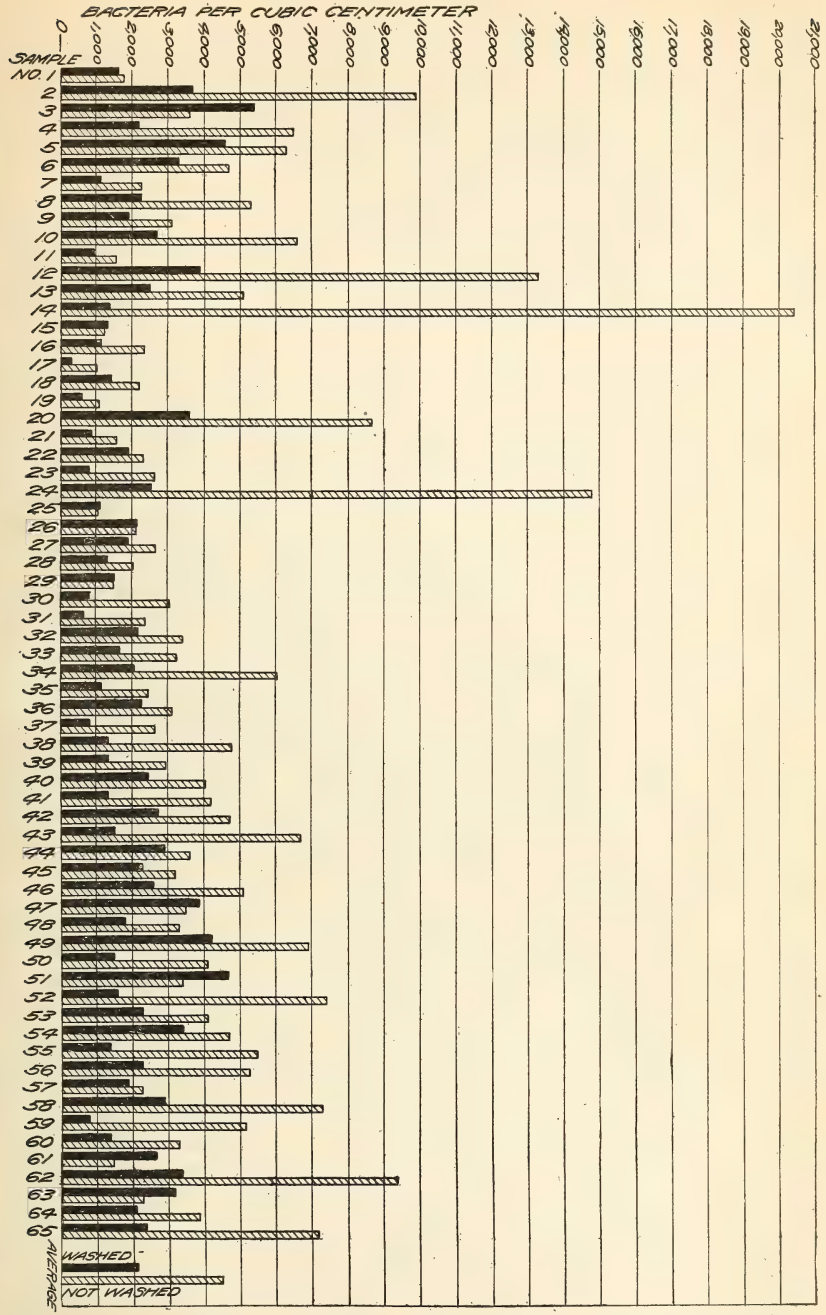


FIG. 10.—Effect of washing the udder and teats on the bacterial content of milk.

almost always a lower count than that from the unwashed udders. The results again lead to the conclusion, as in Experiment No. 3, that three simple factors are necessary for the production of milk practically free from visible dirt and with a low bacterial content when drawn, namely, sterilized utensils, clean cows (especially the udder and teats), and the small-top pail.

During Experiment No. 4 the udders of two cows were washed and two left unwashed, and frequently the practice was reversed. The change was made in order to eliminate the bacterial variation due to a difference in number of bacteria in the milk from the udder of each cow.

Occasionally the bacterial content of the middle milk drawn directly from the cow was determined, as in Experiment No. 3. The average bacterial content of such milk drawn directly from the unwashed udders was 757 per cubic centimeter, and from the washed udders 739. Subtracting these numbers from the averages shown in Table 4, there remain differences of 3,767 bacteria per cubic centimeter in the case of the unwashed udders and 1,415 in the case of the washed udders, which represent the external contamination. However, as already pointed out in connection with the previous experiment, there is probably less external contamination than the figures show.

The small additions of bacteria in milk from both washed and unwashed udders must be kept in mind, as they represent the total external contamination caused by factors formerly regarded as important but which have not been considered in these experiments in the production of low-count milk, which also was relatively free from visible sediment.

In order to show further that the fresh milk produced under such conditions was of high quality from a bacteriological standpoint and compared closely with the middle milk as drawn from the udder, the bacterial groups in a number of samples were determined by what is designated as the milk-tube method. This consisted of picking off each colony on a plate and inoculating into litmus-milk tubes. Tubes were incubated for 14 days at 30° C. (86° F.), and the bacteria from the plate were then divided into groups according to the reactions produced. By that method it was possible to divide the bacteria developing on a plate into 6 groups, namely, the acid-forming, coagulating-acid forming, the inert (which produce no change in milk), the alkali-forming, the peptonizing, and the acid-coagulating peptonizing groups. A number of samples of milk were studied by that method, and as often as possible samples were taken directly from the udder at the same milking. The results of the

work, showing the per cent of the various groups found in the regular milk and the corresponding samples of middle milk directly from the udder, are shown in Table 5. It is interesting to note that the average per cent of the bacterial groups in the milk checks very closely with the average of those in the milk taken directly from the udder. Taking the bacterial groups and counts into consideration, it seems evident that milk produced under the conditions of the experiment was of a high quality from a bacteriological standpoint and was very similar to that taken directly from the udder of the cow. The results of the experiment agree closely with those obtained by North (2), who found it possible to produce low-count milk by the use of small-top, sterilized pails in an old barn.

TABLE 5.—*A comparison of the bacterial groups found in clean milk of low bacterial count and in milk directly from the udder.*

BACTERIAL GROUPS IN MILK SAMPLES.

Date.	Sample No.	Acid coagulating.	Acid.	Inert.	Alkali.	Peptonizing.	Acid coagulating (peptonizing).
1916.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Feb. 29	9	44.45	12.96	25.92	0	0	16.67
Feb. 29	10	0	57.14	37.14	0	5.72	0
Mar. 1	11	47.62	4.76	14.29	0	0	33.33
Mar. 1	12	0	17.56	75.68	0	6.76	0
Mar. 3	19	69.40	10.39	14.75	0	0	5.46
Mar. 17	66	63.06	5.09	17.19	.64	11.48	2.54
Mar. 24	91	7.00	85.00	3.00	2.00	3.00	0
Mar. 24	92	75.30	10.24	11.44	3.02	0	0
Average		38.36	25.39	24.93	.64	3.37	7.25

BACTERIAL GROUPS IN MILK DIRECTLY FROM THE UDDER.

Date.	Cow No.	Acid coagulating.	Acid.	Inert.	Alkali.	Peptonizing.	Acid coagulating (peptonizing).
1916.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Feb. 29	2	19.00	39.00	36.00	1.00	5.00	0
Feb. 29	23	0	97.81	0	0	2.19	0
Feb. 29	26	82.86	8.57	8.57	0	0	0
Mar. 9	2	28.04	64.02	3.27	0	4.67	0
Mar. 9	23	5.11	87.66	3.83	0	0	3.40
Mar. 9	26	85.71	14.29	0	0	0	0
Mar. 16	2	68.34	12.08	5.00	0	0	14.58
Mar. 16	23	2.94	88.82	1.18	0	0	7.06
Mar. 16	26	77.09	0	2.08	0	2.08	18.75
Mar. 24	23	5.78	72.83	14.46	1.73	1.73	3.47
Mar. 24	26	64.58	16.67	16.67	0	2.08	0
Average		39.95	45.61	8.28	.25	1.61	4.29

EXPERIMENT NO. 5. (COWS AND FLOOR DIRTY, MANURE REMOVED WEEKLY, UTENSILS STERILIZED.)

This experiment was conducted under the same conditions as Experiment No. 2. Having determined the essential factors necessary for the production of fresh milk of low bacterial content, it was considered advisable to reproduce the original conditions in order to check the three factors again. Consequently, in the experiment the cows were allowed to get dirty and the manure was removed only once a week, but the other conditions of the barn were not changed. The object was to determine the factor of dirty cows; therefore, the utensils were sterilized in order not to add another factor. The condition of the barn and of the cows is illustrated in figures 11 and 12, respectively. Particular attention is directed to the extremely large quantity of filth on the floor of the barn.

During the experiment, which continued from April 11 to May 6, 1916, 41 samples of milk were examined from both small-top and open pails. The average count of samples from the former was 24,439, and from the latter 86,212 bacteria per cubic centimeter, as shown in Table 6.

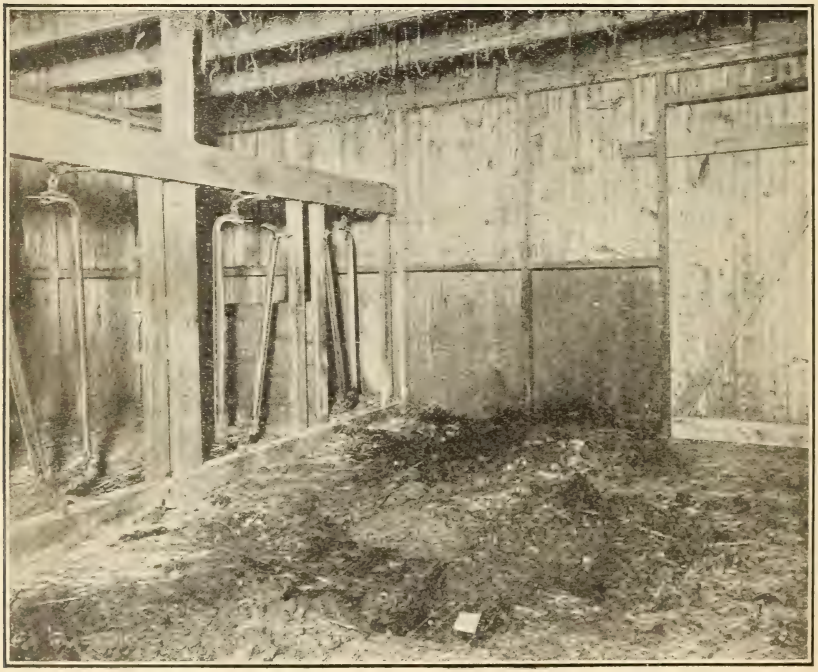


FIG. 11.—Condition of barn during Experiment No. 5.

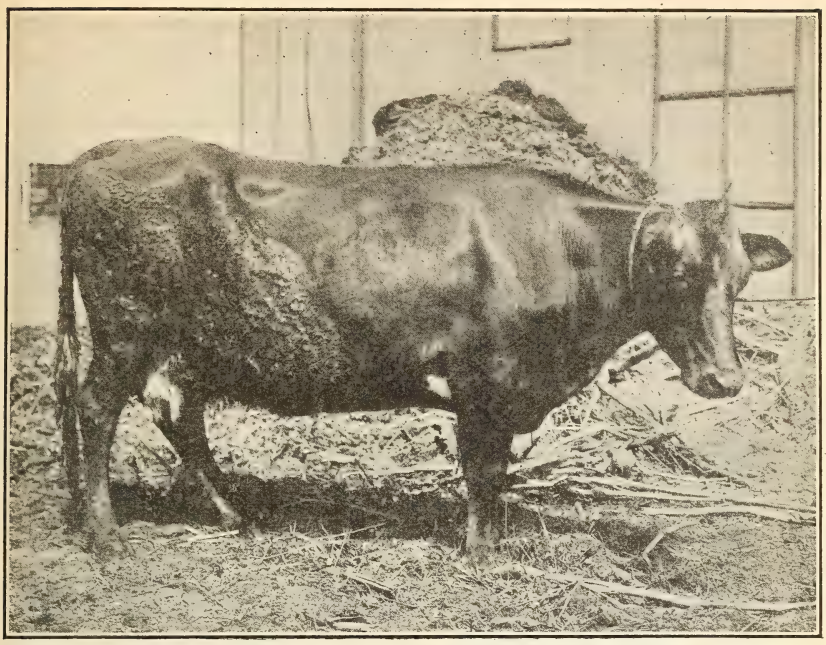


FIG. 12.—Condition of one of the cows during Experiment No. 5.

TABLE 6.—*Bacteria per cubic centimeter in dual samples of fresh milk produced under conditions described in Experiment No. 5.*

Date.	Sample No.	Open pail.	Small-top pail.	Date.	Sample No.	Open pail.	Small-top pail.
1916.				1916.			
Apr. 11, a. m.	1	10,600	4,300	Apr. 26, a. m.	23	19,600	7,500
Apr. 11, p. m.	2	4,500	4,800	Apr. 26, p. m.	24	5,600	3,500
Apr. 12, a. m.	3	8,100	5,600	Apr. 27, a. m.	25	69,000	7,200
Apr. 12, p. m.	4	2,400	2,500	Apr. 27, p. m.	26	9,400	1,900
Apr. 13, a. m.	5	13,900	10,800	Apr. 28, a. m.	27	66,000	17,700
Apr. 13, p. m.	6	6,400	6,100	Apr. 28, p. m.	28	10,800	1,900
Apr. 14, a. m.	7	165,000	26,900	Apr. 29, a. m.	29	53,000	31,000
Apr. 14, p. m.	8	360,000	105,000	Apr. 29, p. m.	30	29,000	3,500
Apr. 15, a. m.	9	240,000	29,800	May 1, p. m.	31	15,900	7,300
Apr. 17, a. m.	10	83,000	14,600	May 2, a. m.	32	8,900	6,100
Apr. 17, p. m.	11	112,000	31,300	May 2, p. m.	33	8,100	2,800
Apr. 18, a. m.	12	65,000	19,700	May 3, a. m.	34	16,100	10,200
Apr. 18, p. m.	13	58,000	18,200	May 3, p. m.	35	3,500	13,100
Apr. 19, a. m.	14	121,000	78,000	May 4, a. m.	36	4,100	8,400
Apr. 19, p. m.	15	144,000	21,100	May 4, p. m.	37	2,600	3,100
Apr. 20, a. m.	16	276,000	122,000	May 5, a. m.	38	65,000	23,000
Apr. 20, p. m.	17	112,000	72,000	May 5, p. m.	39	11,500	6,600
Apr. 21, a. m.	18	163,000	79,000	May 6, a. m.	40	61,000	10,900
Apr. 24, a. m.	19	940,000	166,000	May 6, p. m.	41	11,400	3,700
Apr. 24, p. m.	20	158,000	9,600				
Apr. 25, a. m.	21	16,500	3,200	Average		86,212	24,439
Apr. 25, p. m.	22	4,800	2,100				

If the average bacterial counts in the experiment are compared with those in Table 2, a similar experiment, it will be seen that the average count from the small-top pail was 24,439 in one series and 17,027 in the other. The open pail showed a greater variation, being 86,212 in one case and 22,677 in the other. In the last series with the open pail (Table 6) there are a few high counts which

raise the average greatly. The figures are of interest because with similar barn conditions, dirty cows, and the manure removed weekly, practically the same average number of bacteria were introduced at periods of time which were about six months apart. The results again show that the number of bacteria introduced through manure was not so large as had been expected.

An examination of Table 6 shows the value of the small-top pail, which is most strikingly shown in graphic form in figure 13.

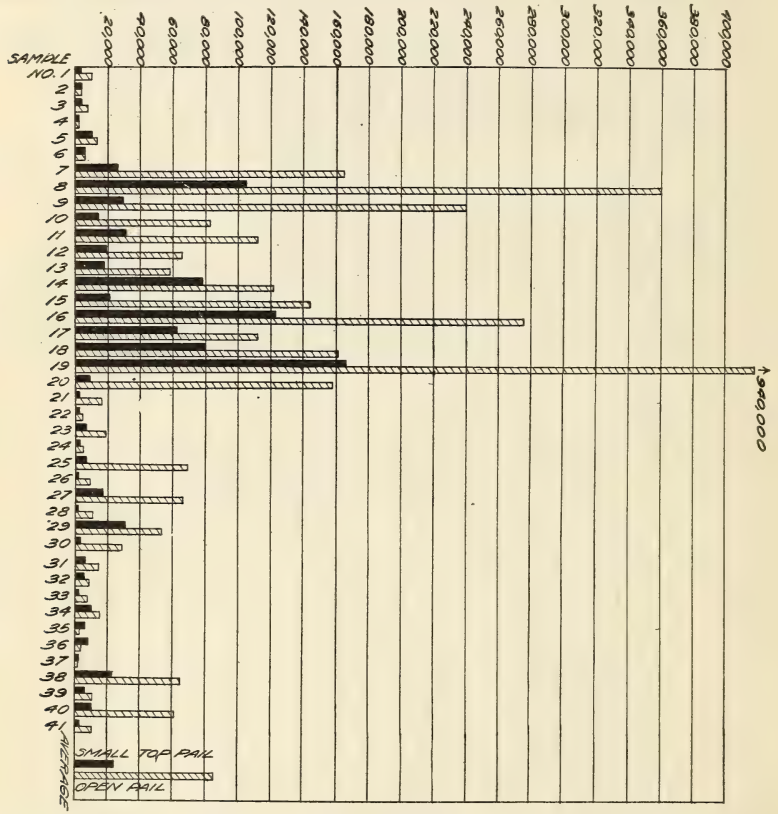


FIG. 13.—Bacterial content of milk from sterilized small-top and open pails during Experiment No. 5.

EXPERIMENT NO. 6. (COWS AND FLOORS DIRTY, MANURE REMOVED WEEKLY, UTENSILS NOT STERILIZED.)

The conditions of this experiment were similar to those of Experiment No. 1. Table 7, covering the period from May 8 to 31, 1916, shows the average count of 36 samples of milk from the small-top pail to be 114,497, compared with 153,905 bacteria per cubic centimeter for the open pail. A comparison of the averages with those in Experiment No. 1, results of which are given in Table 1, shows that the counts in the latter experiment were considerably higher, which may be explained by the variable bacterial content of unsterilized utensils.

TABLE 7.—*Bacteria per cubic centimeter in dual samples of fresh milk produced under conditions described in Experiment No. 6.*

Date.	Sample No.	Open pail.	Small-top pail.	Date.	Sample No.	Open pail.	Small-top pail.
1916.				1916.			
May 8, a. m.	1	149,000	55,000	May 22, p. m.	20	168,000	125,000
May 9, p. m.	2	53,000	12,200	May 23, a. m.	21	202,000	230,000
May 10, a. m.	3	22,500	18,100	May 23, p. m.	22	279,000	201,000
May 11, p. m.	4	39,000	19,500	May 24, a. m.	23	332,000	265,000
May 12, a. m.	5	6,800	12,400	May 24, p. m.	24	227,000	148,000
May 12, p. m.	6	36,300	6,100	May 25, a. m.	25	215,000	168,000
May 13, a. m.	7	108,000	71,000	May 25, p. m.	26	198,000	86,000
May 13, p. m.	8	48,000	40,000	May 26, a. m.	27	209,000	157,000
May 15, a. m.	9	82,000	193,000	May 26, p. m.	28	181,000	78,000
May 15, p. m.	10	34,000	56,000	May 27, a. m.	29	176,000	186,000
May 16, a. m.	11	115,000	169,000	May 27, p. m.	30	196,000	93,000
May 16, p. m.	12	126,000	166,000	May 29, a. m.	31	256,000	128,000
May 17, a. m.	13	207,000	210,000	May 29, p. m.	32	240,000	312,000
May 17, p. m.	14	151,000	42,000	May 30, a. m.	33	338,000	161,000
May 18, a. m.	15	154,000	68,000	May 30, p. m.	34	191,000	94,000
May 18, p. m.	16	99,000	74,000	May 31, a. m.	35	99,000	74,000
May 19, a. m.	17	167,000	94,000	May 31, p. m.	36	94,000	63,000
May 21, p. m.	18	126,000	87,600				
May 22, a. m.	19	216,000	159,000	Average.		153,905	114,497

In all the experiments the utensils were probably washed more carefully than on the average farm, and to show how many bacteria may be introduced into milk under dirty conditions when utensils are not washed until just before milking, figures from another series of experiments may be of interest. In the latter experiments milk produced with the use of the small-top pails showed an average count of 1,309,000 compared with 2,015,000 bacteria per cubic centimeter in open pails. While in this experiment utensils were handled in an extremely careless manner, the results show that a large number of bacteria may be introduced from unsterilized utensils.

While the average count from the open pail was higher than from the small-top pail, the value of the latter can not be accurately determined from the results, because the utensils were not sterilized. In a general way, however, the small-top pail has some value even under the conditions described.

The results obtained in Experiment No. 6 confirm those obtained in our first experiment and indicate that the greatest contamination of milk comes from the use of unsterilized utensils.

EXPERIMENT NO. 7. (COWS AND FLOOR CLEAN, MANURE REMOVED DAILY, UDDERS AND TEATS OF COWS WASHED, UTENSILS STERILIZED.)

Experiment No. 7 was conducted under the same conditions as Experiment No. 4 except that the cows were not bedded. The general condition of the barn during the experiment is illustrated in figure 14 and that of the cows in figure 15. The floor of the stable was kept comparatively clean, the manure was removed daily, the utensils were sterilized, and at each milking the cows were cleaned and udders and teats were wiped with a damp cloth. Only a few samples of milk were taken during this experiment, which continued

from June 5 to 15, 1916. The average bacterial count of 15 samples from the small-top pail was 2,667 and from the open pail 4,947 bacteria per cubic centimeter, as shown in Table 8. In the previous series (Table 4) the average bacterial count was 2,154, compared with 2,667, the average count obtained in this series. The figures are particularly interesting, as they represent average counts of milk produced under similar conditions with periods of time about three months apart. The bacterial counts of milk from the small-top compared with open pails again show the value of the former type.

TABLE 8.—*Bacteria per cubic centimeter in dual samples of fresh milk produced under conditions described in Experiment No. 7.*

Date.	Sample No.	Open pail.	Small-top pail.	Date.	Sample No.	Open pail.	Small-top pail.
1916.				1916.			
June 5, p. m.	1	4,900	1,300	June 10, a. m.	10	3,100	2,300
June 6, a. m.	2	21,300	1,200	June 10, p. m.	11	8,400	1,600
June 6, p. m.	3	3,700	6,400	June 12, a. m.	12	3,800	5,400
June 7, a. m.	4	3,100	2,300	June 12, p. m.	13	1,700	4,600
June 7, p. m.	5	4,900	2,200	June 13, a. m.	14	1,500	2,100
June 8, a. m.	6	3,700	1,400	June 13, p. m.	15	900	2,200
June 8, p. m.	7	2,800	2,400				
June 9, a. m.	8	7,500	3,300	Average		4,947	2,667
June 9, p. m.	9	2,900	1,300				

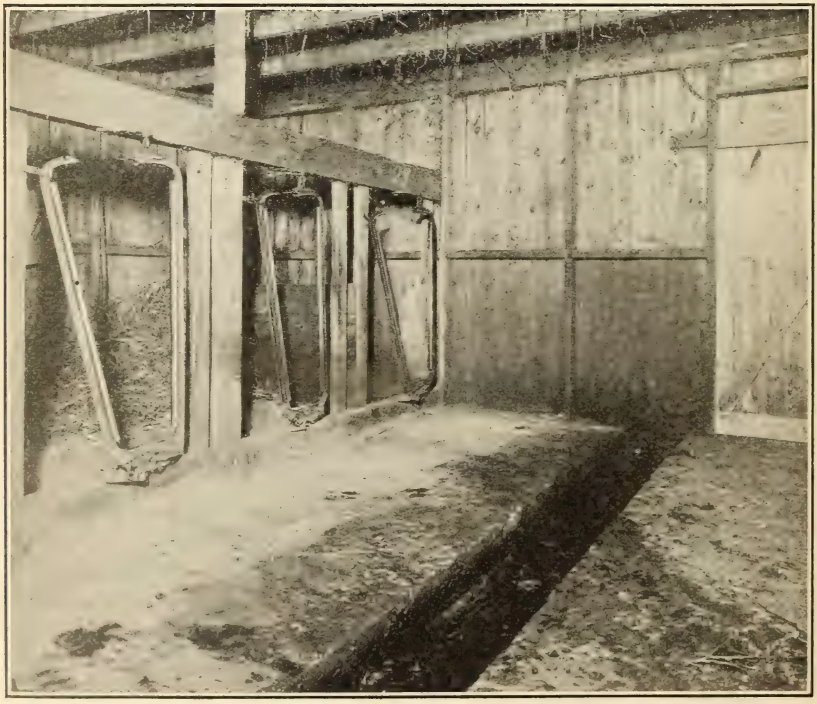


FIG. 14.—Condition of barn during Experiment No. 7.

During this experiment the average count of the middle milk taken directly from the udder of two cows was 1,172 bacteria per cubic centimeter, which, subtracted from 2,667, the count of the entire milking which was milked into small-top pails, leaves 1,495, or the number of bacteria per cubic centimeter introduced into the small-top pail by external contamination.

FIG. 15.—Condition of the flank and udder of one of the cows during Experiment No. 7.

Similarly the average udder count of middle milk of the two cows milked into open pails was 1,557, which, when subtracted from the average of the open pail, 4,947, gives a difference of 3,390 bacteria per cubic centimeter to represent the number introduced by external contamination.

In this final experiment we again used a few simple factors, namely, sterilized utensils, clean cows with clean udders and teats, and the small-top pail. The figures confirm the previous results.

CONTAMINATION OF MILK BY UNSTERILIZED UTENSILS.

In this work the results have indicated that generally the greatest contamination of milk comes from the use of unsterilized utensils. Since that factor is so important in the production of low-count milk it deserves special consideration, and therefore additional data on the subject are presented.

Table 9 shows the results of the bacterial examination of 60 samples of milk from both sterilized and unsterilized small-top pails. Each number represents two samples taken at the same milking, when two cows were milked into a sterilized pail and two into an unsterilized one. All the cows were cleaned and bedded, but the udders were not washed. The 60 samples from the sterilized pail showed an average bacterial count of 6,306, compared with 73,308 for the unsterilized pail, a difference of 67,002, which represents the average number of bacteria per cubic centimeter introduced through unsteril-

ized utensils. The results appear graphically in figure 16, which shows the remarkable difference between the bacterial content of milk from sterilized and unsterilized utensils. The highest bacterial count of all the samples from sterilized utensils was 21,500 and from unsterilized utensils 284,000 bacteria per cubic centimeter.

TABLE 9.—*Bacteria per cubic centimeter in dual samples of fresh milk when sterilized and unsterilized utensils were used.*

Date.	Sample No.	Small-top pail.		Date.	Sample No.	Small-top pail.	
		Sterilized.	Unsterilized.			Sterilized.	Unsterilized.
1916.				1916.			
Jan. 19, p. m.	1	3,700	17,500	Feb. 8, a. m.	32	16,700	56,000
Jan. 20, a. m.	2	5,800	112,000	Feb. 8, p. m.	33	2,900	37,000
Jan. 20, p. m.	3	6,900	47,600	Feb. 9, a. m.	34	6,800	18,300
Jan. 21, a. m.	4	12,500	38,200	Feb. 9, p. m.	35	1,200	149,000
Jan. 21, p. m.	5	4,900	18,400	Feb. 10, a. m.	36	3,100	42,000
Jan. 23, p. m.	6	8,100	126,000	Feb. 10, p. m.	37	1,500	42,500
Jan. 24, a. m.	7	3,300	68,000	Feb. 11, a. m.	38	5,400	37,100
Jan. 24, p. m.	8	6,900	9,700	Feb. 11, p. m.	39	2,900	94,000
Jan. 25, a. m.	9	3,800	66,000	Feb. 12, a. m.	40	6,300	33,900
Jan. 25, p. m.	10	4,200	16,500	Feb. 13, p. m.	41	2,500	21,200
Jan. 26, a. m.	11	6,800	85,000	Feb. 14, p. m.	42	4,200	19,800
Jan. 26, p. m.	12	6,600	18,600	Feb. 15, a. m.	43	12,500	55,200
Jan. 27, a. m.	13	21,500	27,900	Feb. 15, p. m.	44	7,500	68,000
Jan. 27, p. m.	14	4,500	5,100	Feb. 16, a. m.	45	4,500	.....
Jan. 28, a. m.	15	4,900	48,500	Feb. 16, p. m.	46	1,500	117,000
Jan. 28, p. m.	16	3,700	141,000	Feb. 17, a. m.	47	6,300	195,000
Jan. 29, a. m.	17	7,800	54,000	Feb. 17, p. m.	48	3,100	65,000
Jan. 30, p. m.	18	3,400	203,000	Feb. 18, a. m.	49	6,900	152,000
Jan. 31, a. m.	19	17,500	98,000	Feb. 18, p. m.	50	8,900	103,000
Jan. 31, p. m.	20	2,000	102,000	Feb. 19, a. m.	51	8,500	106,000
Feb. 1, a. m.	21	15,800	64,700	Feb. 20, p. m.	52	5,800	62,000
Feb. 1, p. m.	22	9,300	92,000	Feb. 22, p. m.	53	2,500	83,000
Feb. 2, p. m.	23	3,500	97,000	Feb. 23, a. m.	54	6,200	39,700
Feb. 3, a. m.	24	5,100	32,200	Feb. 23, p. m.	55	6,200	97,000
Feb. 3, p. m.	25	3,000	28,200	Feb. 24, a. m.	56	8,900	97,000
Feb. 4, a. m.	26	9,900	7,400	Feb. 24, p. m.	57	5,100	133,000
Feb. 4, p. m.	27	2,700	37,500	Feb. 25, a. m.	58	3,900	130,000
Feb. 5, a. m.	28	19,300	11,800	Feb. 25, p. m.	59	4,600	131,000
Feb. 6, p. m.	29	2,600	284,000	Feb. 26, a. m.	60	3,200	134,000
Feb. 7, a. m.	30	5,300	54,000				
Feb. 7, p. m.	31	2,900	68,000	Average		6,306	73,308

The diagram shows that in two cases, numbers 26 and 28, the milk from the sterilized utensils was slightly higher in bacterial content than that from the unsterilized. In both cases the counts were relatively low, which indicates that the unsterilized utensils in these particular cases were thoroughly washed in very hot water. Throughout the series, as soon as the samples were taken the pails and cans were washed in hot water—54.4° C. (130° F.)—in which washing powder had been dissolved. The insides of the cans and pails were scrubbed with a brush. After washing, the cans were inverted and remained uncovered until the next milking. It is evident that they were washed better than they would have been on the average farm. By this method of handling it is apparent that the number of bacteria in the unsterilized cans would be smaller than in those in which milk had stood for a considerable time, for in the latter case there is an opportunity for a great multiplication of bacteria. The higher the bac-

terial count in the milk, the higher it would be in the can after the milk is poured out. The more milk there is left in the can before washing, the higher the count would probably be after washing, and consequently the greater the contamination of the fresh milk placed in the can. The method of handling utensils in the experiment ex-

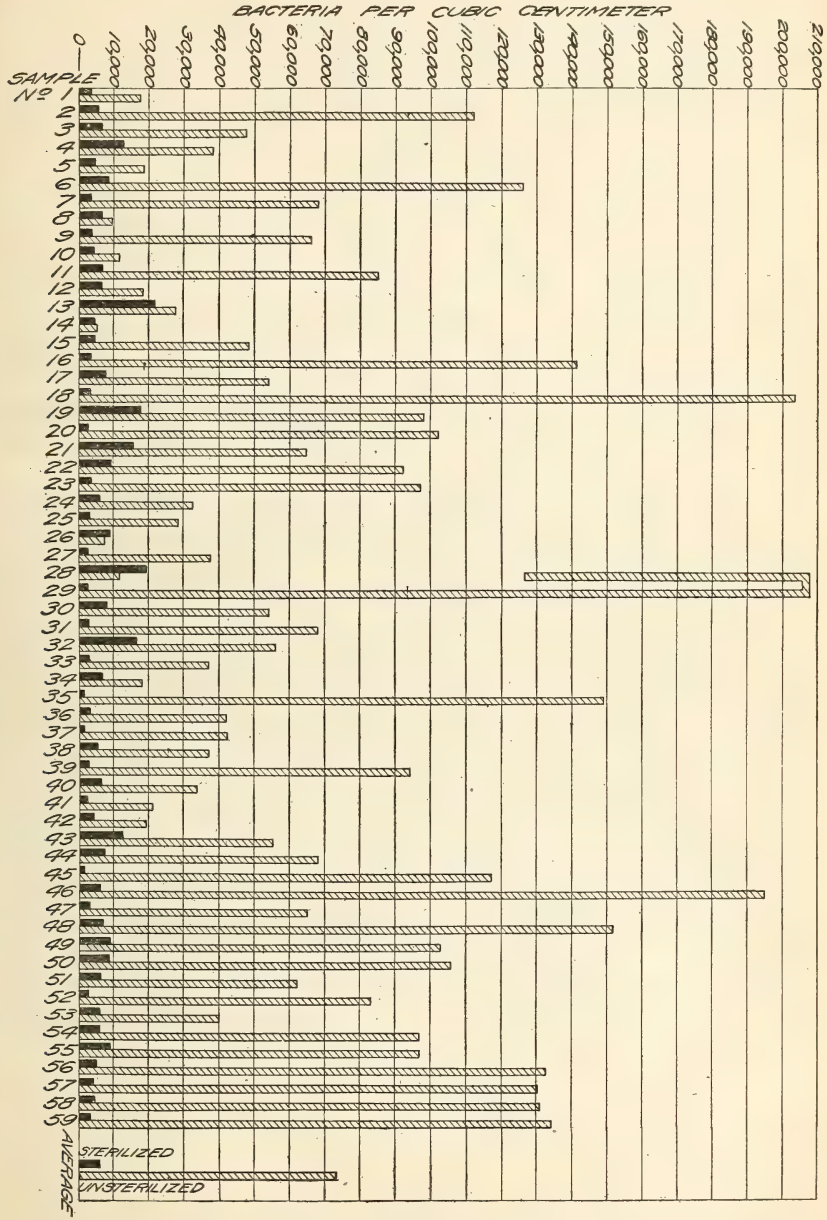


FIG. 16.—Bacterial contents of milk from sterilized (black) and unsterilized (white) utensils.

plains, therefore, the relatively low count found in milk placed in the unsterilized utensils.

The number of bacteria introduced into milk by unsterilized utensils is extremely variable because of the many different ways in which the utensils may be handled. To show the variation other experiments were conducted, the results of which are shown in Table 10. In these experiments the manure was removed only twice a week and the cows were dirty. Under the conditions the average count of 30 samples of milk from sterilized utensils was 31,040 bacteria per cubic centimeter, which represents the contamination of the milk, largely by manure, but does not include that from unsterilized utensils. Under the same conditions 50 samples of milk were taken, directly after milking, from washed but not sterilized utensils. The average count of this series of samples was 666,520. Deducting 31,040, the average count from sterilized utensils, the remainder, 635,480, represents the average bacterial contamination per cubic centimeter of milk resulting from unsterilized utensils. Referring to the contamination by unsterilized utensils discussed in the previous experiment and shown in Table 9, it may be seen that the contamination in the two experiments was very different, being in the former relatively low and in the latter very high.

To show further the variability of the factor of unsterilized utensils, another series of samples was examined under the same barn conditions but with utensils treated in a different manner. After milking, the milk was poured from the utensils, but the drainings were allowed to remain. The utensils were placed upright on the floor until the next milking, or about eight hours later, when they were washed in the same manner as in the previous experiments. The 20 samples of milk taken under these conditions averaged 1,667,000 bacteria per cubic centimeter, as shown in Table 10. The count was nearly three times that of the average of 50 samples in which the utensils were washed immediately after milking but not sterilized. By deducting the average figure of 31,040 bacteria obtained in the samples from sterilized utensils, the average number introduced from unsterilized ones held eight hours before washing was about 1,635,000 bacteria per cubic centimeter. While that method of handling utensils may not represent average conditions in practice, it is not unusual. The results indicate that a very large number of bacteria may be introduced into milk from washed, unsterilized utensils.

TABLE 10.—*Number of bacteria per cubic centimeter introduced into milk through unsterilized utensils.*

Sample No.	Utensils sterilized.	Utensils washed directly after milking.	Utensils held 8 hours before washing.	Sample No.	Utensils sterilized.	Utensils washed directly after milking.	Utensils held 8 hours before washing.
1	27,000	225,000	670,000	27	24,500	1,310,000	.....
2	58,000	1,140,000	820,000	28	25,000	520,000	.....
3	54,000	270,000	3,300,000	29	16,500	750,000	.....
4	83,000	620,000	1,800,000	30	10,500	460,000	.....
5	28,000	680,000	1,170,000	31	.....	320,000	.....
6	96,000	1,080,000	1,440,000	32	.....	440,000	.....
7	11,800	490,000	620,000	33	.....	180,000	.....
8	39,000	850,000	860,000	34	.....	490,000	.....
9	23,600	840,000	570,000	35	.....	318,000	.....
10	98,000	1,450,000	630,000	36	.....	497,000	.....
11	21,600	2,400,000	1,300,000	37	.....	580,000	.....
12	12,400	1,950,000	2,720,000	38	.....	440,000	.....
13	10,200	260,000	1,120,000	39	.....	780,000	.....
14	22,000	610,000	1,840,000	40	.....	710,000	.....
15	12,100	340,000	1,080,000	41	.....	590,000	.....
16	42,000	630,000	1,920,000	42	.....	310,000	.....
17	16,400	179,000	1,160,000	43	.....	450,000	.....
18	22,800	366,000	3,820,000	44	.....	230,000	.....
19	24,000	304,000	2,200,000	45	.....	190,000	.....
20	37,000	460,000	4,300,000	46	.....	230,000	.....
21	13,500	1,320,000	.....	47	.....	182,000	.....
22	57,000	790,000	.....	48	.....	340,000	.....
23	14,200	1,600,000	.....	49	.....	560,000	.....
24	15,500	295,000	.....	50	.....	670,000	.....
25	8,000	1,940,000	.....				
26	7,600	690,000	.....	Average...	31,040	666,520	1,667,000

Several determinations of the total number of bacteria in washed cans and pails were made just before milking. They were obtained as follows: Four hundred cubic centimeters of sterile water was placed in each utensil and vigorously shaken, the contents were then poured into a sterile receptacle and the number of bacteria determined in the usual way. The results of some of the determinations are shown in Table 11. Five-gallon cans were washed, as has been described, with hot water at approximately 54.4° C. (130° F.) in which washing powder was dissolved. The interior of the utensils was scrubbed with a brush, then rinsed, inverted, and left uncovered in the milk house. The number of bacteria per can ranged from 292,000,000 to 5,520,000,000 and in the pails from 2,400 to 12,600,000. Table 11 also shows two counts of pails and cans which had been held eight hours before being washed, one can showing 15,600,000,000 and the other 16,800,000,000 bacteria, while the pails showed 44,000,000 and 700,000,000 bacteria, respectively. The results show the great variation that may occur in can and pail counts when held under different conditions.

TABLE 11.—*Total number of bacteria found in clean-washed but unsterilized utensils.*

Series No.	Washed can.	Washed pail.	Series No.	Washed can.	Washed pail.
1	728,000,000	76,400	8	292,000,000	4,200,000
2	816,000,000	2,600	9	1,220,000,000	652,000
3	860,000,000	2,400	10	1,180,000,000	2,200,000
4	5,520,000,000	17,600	11	1,640,000,000	10,400,000
5	624,000,000	8,800	12	[1] 16,800,000,000	[1] 700,000,000
6	870,000,000	12,600,000	13	[1] 15,600,000,000	44,000,000
7	1,580,000,000	1,380,000			

[1] Held 8 hours before washing.

During the work it was thought that one rinsing of a can with sterile water probably did not remove all the bacteria from the interior. To determine the point several tests were made, the results of which are shown in Table 12. In the first test the can was rinsed twice, with 400 cubic centimeters of sterile water each time. The first rinsing showed 860,000,000 bacteria and the second 478,800,000, or a total of 1,338,800,000 bacteria in the can. In a second test, in which the can was rinsed three times, each rinsing showed large numbers of bacteria, the count being lower after each rinsing. In a third test, in which four rinsings were made, the last one still removed a large number of bacteria. It follows from these results that one rinsing removes only a portion of the bacteria from the can, and therefore is not a true measure of the number of bacteria present. The highest total count per 5-gallon can in that test was 8,876,000,000 bacteria. A simple calculation proves that if this can were filled with milk, 469,132 bacteria would be added to each cubic centimeter through contamination from the can. This merely shows the possibility of great contamination from unsterilized utensils.

TABLE 12.—*Effect of several rinsings in determining the number of bacteria in cans.*

Number of rinsing.	Number of bacteria per washed can.
1	860,000,000
2	478,800,000
Total	1,338,800,000
1	5,520,000,000
2	2,640,000,000
3	716,000,000
Total	8,876,000,000
1	624,000,000
2	316,000,000
3	109,000,000
4	72,000,000
Total	1,121,000,000

As a matter of additional interest, some experiments were conducted which show that bacteria grow in washed cans which are closed before they are thoroughly dried. To illustrate the point, two 5-gallon cans were sterilized, then one was filled with milk, which was immediately poured into the other, and that in turn immediately emptied. The operation was performed in order to introduce into each can approximately the same number of bacteria. Each can was then washed in exactly the same manner, the excess of water being shaken out and the cover replaced. A determination of the number of bacteria in one of the freshly washed cans was then made. The other can, which it may be assumed contained approximately the same number of bacteria at that time, was allowed to stand at a warm temperature for 24 hours, when the number of bacteria was determined. An examination of the results in Table 13 shows that in each of the seven tests there was a great increase in the number of bacteria in the cans during the holding period of 24 hours. The importance of drying cans thoroughly after washing, particularly when they are immediately covered, is therefore evident.

TABLE 13.—*Bacterial growth in cans covered before being dried.*

Series No.	Bacteria per can.		Series No.	Bacteria per can	
	Freshly washed.	24 hours after washing.		Freshly washed.	24 hours after washing.
1	960,000	847,000,000	5	99,600	320,000,000
2	618,000	2,612,000,000	6	5,570,000	748,000,000
3	137,000	336,000,000	7	305,000	138,000,000
4	91,000	428,000,000			

Utensils that have not been sterilized, besides adding large numbers of bacteria to milk, introduce types which greatly affect the relation of the various bacterial groups in it. This matter also was investigated, determinations having been made of the bacterial groups in milk drawn directly from the udder, from sterilized utensils, from unsterilized utensils, and from washings of unsterilized cans. Table 14 summarizes the results of this work. Numerous samples from different sources have been averaged in the table. The bacterial groups were determined by the milk-tube method, which has been described.

The bacterial groups in the samples of milk drawn directly from the udder compare very closely with those in the milk from sterilized utensils. It will be noted that in the milk from unsterilized utensils there was a great increase in the percentage of the alkali-forming and peptonizing groups. While the acid-coagulating peptonizing group was not found in milk from utensils not sterilized, it was pres-

ent in the milk drawn directly from the udder. It was not found for the reason that the bacterial count being so great such dilutions had to be used in plating that the small number of bacteria of that type did not appear on the plates. It is also of interest to note that the washings from the unsterilized cans contained high percentages of the alkali-forming bacteria and particularly the peptonizing group. The addition of peptonizing bacteria in large numbers to milk is a matter of considerable importance, since they may be highly undesirable in that they produce putrefactive changes. North has frequently called attention to the importance of the use of sterilized utensils, which has been further emphasized by results obtained by Prucha, Harding, and Weeter (3). The work of these investigators and our own experiments indicate clearly that the use of sterilized utensils is the greatest factor in the production of milk of low bacterial count.

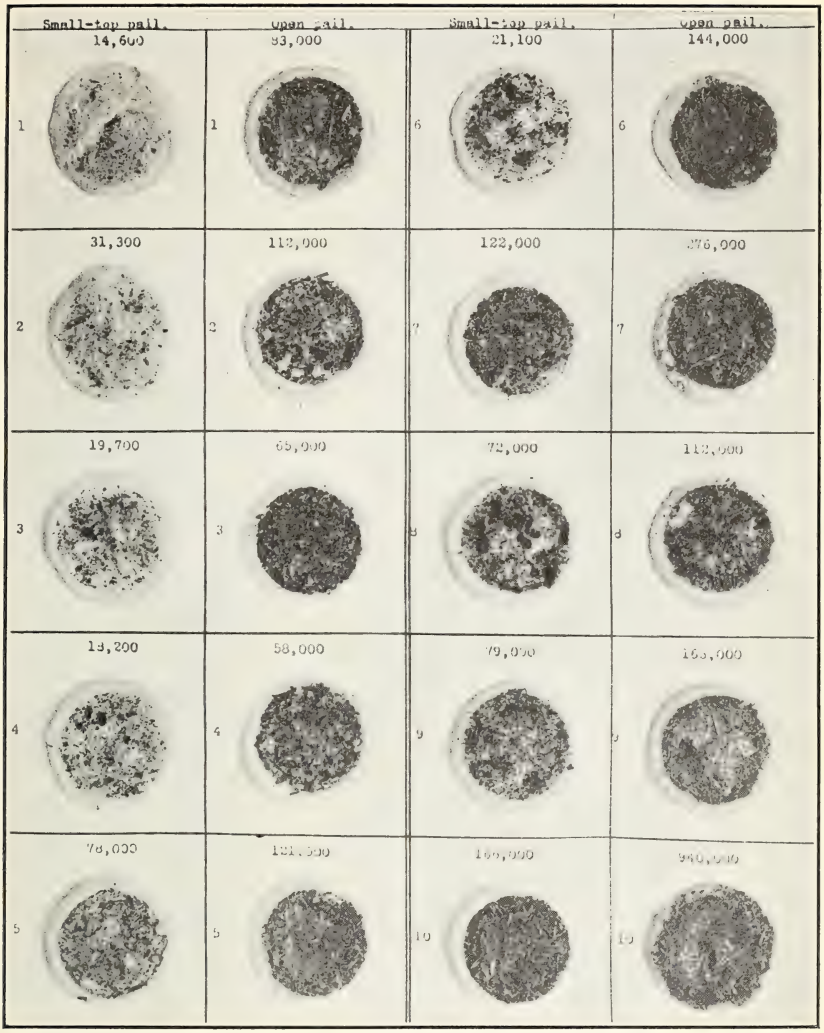
TABLE 14.—*Bacterial groups in milk directly from the udder, in fresh milk from sterilized and unsterilized utensils, and in washings from clean but unsterilized cans.*

Source of sample.	Number of samples averaged.	Bacterial groups.					
		Acid coagulating	Acid.	Inert.	Alkali.	Peptonizing.	Acid coagulating (peptonizing).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Udder	47	46.21	37.25	9.41	0.45	1.36	5.09
Milk from sterilized utensils	19	25.81	39.22	25.51	.71	3.26	5.49
Milk from unsterilized utensils	17	11.54	16.99	31.55	14.14	25.79	0
Washings from unsterilized cans	2	.39	1.85	11.64	19.24	66.87	0

The small dairyman often has difficulty in providing an inexpensive apparatus for sterilizing his utensils. Realizing this, a simple steam sterilizer has been devised in the Dairy Division. The sterilizer, fully described in Farmers' Bulletin 748, entitled "A Simple Steam Sterilizer for Farm Dairy Utensils," is inexpensive to construct and operate and provides a practical method for sterilizing dairy utensils on a small scale. The bulletin will be sent free to anyone on request to the Department of Agriculture.

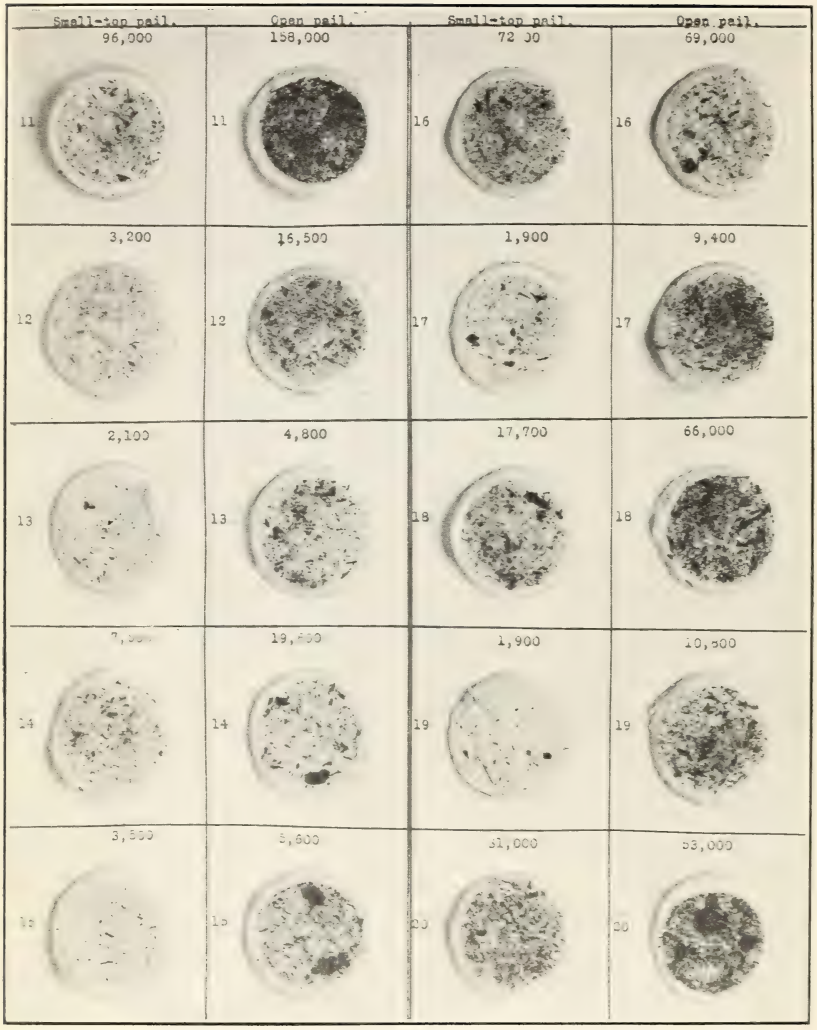
CONTAMINATION OF MILK BY MANURE AND DIRT.

It has been shown that unsterilized utensils are a source of very great contamination of milk, but they are not the only means of contamination. Statements have been made, and possibly it has been the general belief, that the greatest contamination of milk comes from manure and other accumulations of dirt on the body of the cow. The results in these experiments indicate that while that is an important source of contamination from the standpoint of the number



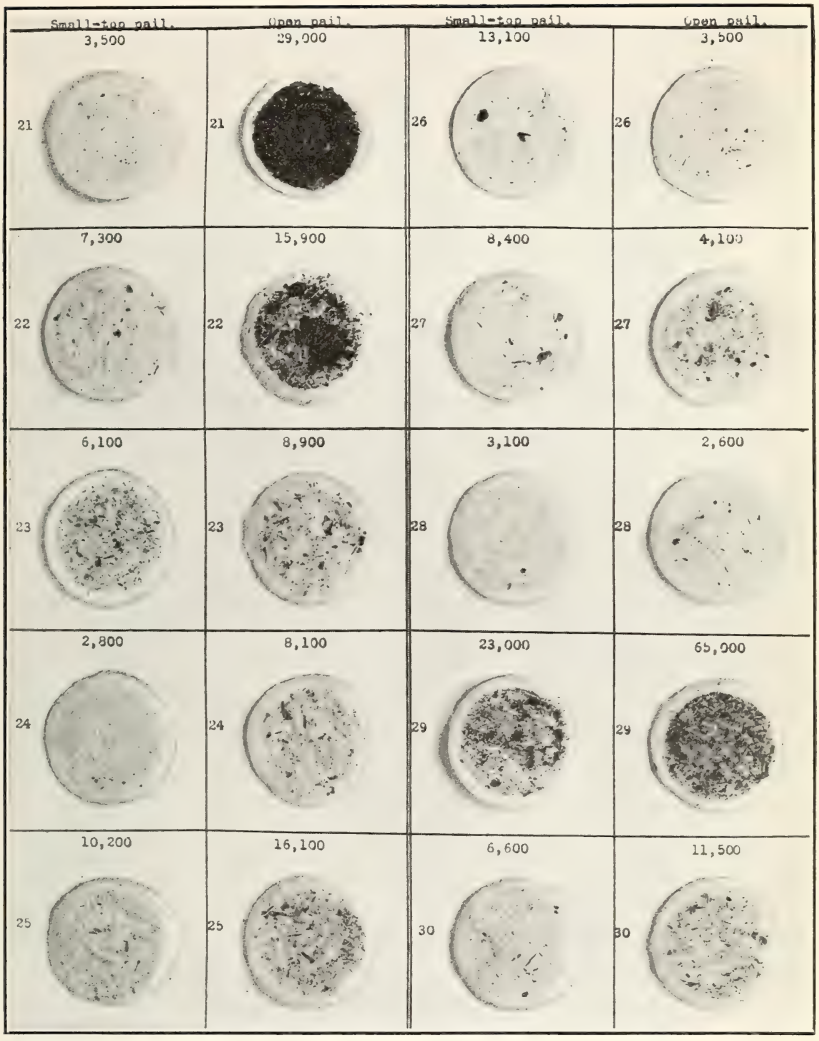
COMPARISON OF SEDIMENT AND BACTERIAL COUNT OF MILK FROM SMALL-TOP AND OPEN PAILS DURING EXPERIMENT NO. 5. BACTERIA PER CUBIC CENTIMETER AND SEDIMENT DISKS FROM ONE PINT OF MILK.

Continued in Plates II and III.



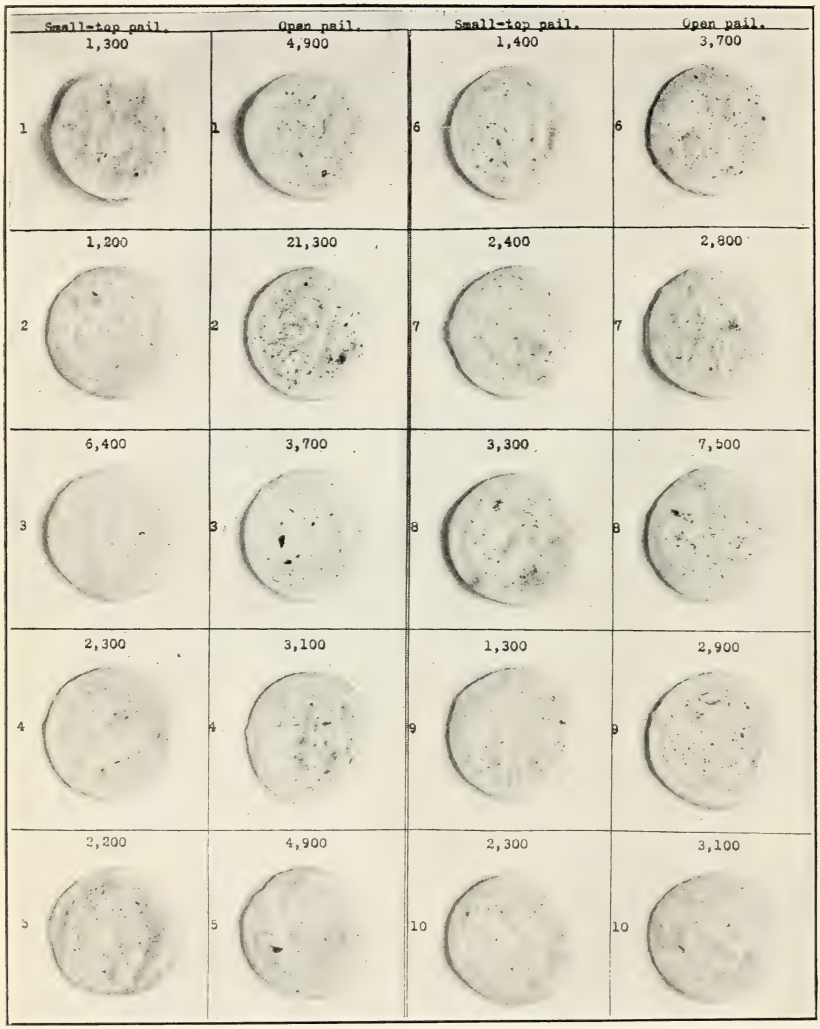
COMPARISON OF SEDIMENT AND BACTERIAL COUNT OF MILK FROM SMALL-TOP AND OPEN PAILS DURING EXPERIMENT NO. 5. BACTERIA PER CUBIC CENTIMETER AND SEDIMENT DISKS FROM ONE PINT OF MILK.

See also Plates I and III.

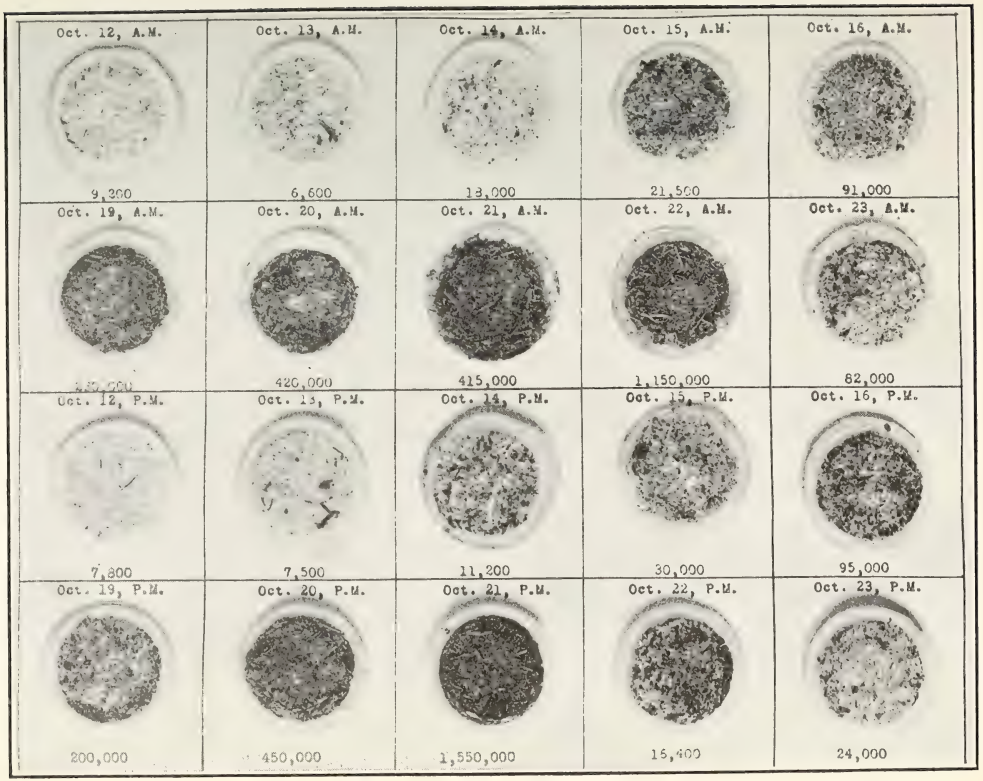


COMPARISON OF SEDIMENT AND BACTERIAL COUNT OF MILK FROM SMALL-TOP AND OPEN PAILS DURING EXPERIMENT NO. 5. BACTERIA PER CUBIC CENTIMETER AND SEDIMENT DISKS FROM ONE PINT OF MILK.

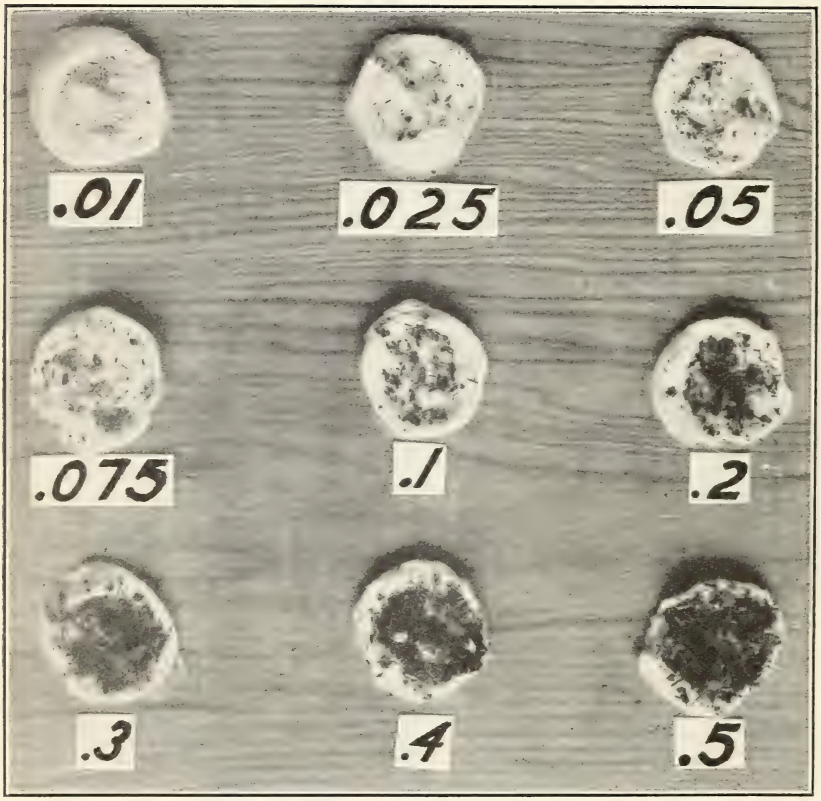
Continued from Plates I and II.



COMPARISON OF THE SEDIMENT AND BACTERIAL COUNT OF MILK FROM SMALL-TOP AND OPEN PAILS DURING EXPERIMENT NO. 7. BACTERIA PER CUBIC CENTIMETER AND SEDIMENT DISKS FROM ONE PINT OF MILK.



RELATION OF THE BACTERIAL COUNT TO THE SEDIMENT TEST. BACTERIA PER CUBIC CENTIMETER AND SEDIMENT DISKS FROM ONE PINT OF MILK.



SEDIMENT DISKS SHOWING FROM 0.01 TO 0.5 GRAM OF FRESH MANURE.

of bacteria introduced, it is a factor of less importance than unsterilized utensils. Nevertheless, dirt and manure should be kept out of milk, not only to help insure the production of milk of low bacterial count, but also to minimize the possibility of infection by disease-producing organisms, particularly that of bovine tuberculosis. It has been shown by Shroeder (4) that cattle having tuberculosis swallow their sputum, so that the tubercle bacilli in it pass through their bodies and into the manure.

The small-top pail was designed for the purpose of helping to prevent the entrance of manure and dirt into milk. Many investigations, among which may be mentioned the work of Stocking (5), also Harding (6) and his associates, and Lamson (7), have shown it to be of great assistance in this connection. Throughout the experiments both the open and small-top pails were used, and attention is again called to the value of the small-top pail in the experiments whether the cows were clean or dirty. Table 15 gives a summary of the average bacterial counts from milk from the sterilized open and small-top pails. Discussion of the results is unnecessary, as they confirm what has been recognized, namely, that lower bacterial counts can be obtained when a small-top pail is used. In all except the last figures in Table 15 the averages represent the counts at the same milking when two cows were milked into open and two into small-top pails. The most interesting point in connection with the figures is the fact that even under extremely dirty conditions relatively low average bacterial counts were obtained. The original cost of a small-top pail is little more than that of an open pail; it is no more expensive to care for and is of distinct value in preventing the entrance of manure and dirt into milk; consequently it should always be used.

TABLE 15.—*Summary of bacterial counts of milk drawn under various conditions into sterilized open and small-top pails.*

Condition of cows and barn floor.	Number of samples averaged.	Bacteria per cubic centimeter.	
		Open pail (sterilized).	Small-top pail (sterilized).
Cows dirty, manure removed once a week	36	22,677	17,027
Cows dirty, manure removed once a week (6 months later)	41	86,212	24,439
Cows dirty, udders and teats clean, manure removed twice a week	23	6,166	2,886
Cows clean, udders and teats washed, manure removed daily	15	4,947	2,667
Cows clean and bedded, udders not washed, manure removed daily	32	8,681	[1] 6,306

[1] 65 samples.

The value of the small-top pail is well illustrated in Plates I, II, and III, in which a series of sediment disks is shown. The cotton disks show the sediment from milk when a small-top and an open

pail were used at the same milking; in each case the bacterial count is shown above the disk. During the work the manure was removed from the stable only twice a week, and as a result the cows were extremely dirty. A study of the disks shows that in nearly every case when the small-top pail was used there was less sediment in the milk. The most striking difference is shown in sample 21. In some samples, however, there was apparently little or no difference, and when the disks from both the small-top and open pails showed little sediment there was, as a rule, less relative difference between the disks from the two types of pails.

The average number of bacteria per cubic centimeter in the 30 samples from the small-top pail was 29,263 and in milk from the open pail 87,380. The most striking difference in the bacterial count is shown in sample 10, where samples from small-top and open pails contained a large quantity of sediment. So far as could be judged, one kind of pail contained about as much as the other, but the bacterial count of the milk from the small-top pail was 166,000 and from the open pail 940,000 bacteria per cubic centimeter. It is interesting to note that in the majority of cases in which the sediment disks showed a large quantity of manure there was a relatively low bacterial count. Occasionally a sample showed a large quantity of sediment and a high count, while other samples containing a similar amount had a low count. This is well illustrated in samples 10 and 21, which represent sediment in milk from the open pail and may be explained by the variation in the number of bacteria in samples of manure.

When the cows were clean and the udders free from visible dirt there was much less difference in the sediment in milk from the small-top and open pails, as is well illustrated in Plate IV, which shows the sediment disks of milk drawn in small-top and open pails under those conditions. The cows were kept clean, the manure was removed daily from the stable, and the udders were wiped with a damp cloth just before milking. One of the cows and the interior of the barn are shown in figures 14 and 15. It must be remembered that the sediment disks represent the sediment in unstrained milk. Of the 10 samples examined, some showed practically no difference in the quantity of sediment in milk from the small-top and open pails, but as a rule the small-top pail contained less sediment and a slightly lower bacterial content. The average number of bacteria per cubic centimeter from the small-top pail in the 10 samples was 2,410 and from the open pail 5,740. It will be noted in sample 2 that milk from the open pail showed 21,300 bacteria per cubic centimeter, which raised the average of all the samples from the open pails.

Throughout the work it was found that, in spite of the variation in the number of bacteria in manure, a fairly constant relation existed between the quantity of sediment and the bacterial count. The relation can be established only when fresh, unstrained milk, handled in sterilized utensils, is examined. Some attempts have been made by investigators to establish a relation between the sediment test and bacterial count in market milk, which, of course, has proved impossible, because the history of the milk was not known.

Campbell (8) draws the following conclusions: "The quantity of sediment or visible dirt present on the disk is no criterion as to the kind or number of bacteria contained in the milk." He made tests with samples of milk which were collected on the railroad station platform from cans as they arrived from various farmers. The conclusion is of course correct, but it should be qualified by a statement as to where the samples were taken. In such cases there are three unknown factors, namely, whether the milk was strained, whether it was handled in sterilized or unsterilized utensils, and what proportion of the bacterial count is due to contamination and what proportion due to growth. If the milk has been strained on the farm it is certain that there is no relation between the sediment and the bacterial count; neither will there be any if the milk has been handled in unsterilized utensils, which may introduce large numbers of bacteria. Neither can any relation be expected unless the comparison is made on fresh milk, since bacteria multiply rapidly unless the milk is held at a low temperature. The only way in which the relation can be established between sediment and the bacterial count is by a study of fresh, unstrained milk at the farm, and where sterilized utensils are used. Under such conditions there is a general relation between the sediment and the bacterial count, as is shown in Plate V, which shows the sediment disks from a pint of milk together with the number of bacteria per cubic centimeter in it. At the beginning of the experiment the floor in the barn was clean, the cows were fairly clean, and for a period of nine days the manure was allowed to accumulate on the floor. During that time the cows were not cleaned; consequently they became dirtier each day. The experiment began on October 12 and continued to October 23, during which time samples of milk were examined from each morning's and night's milking. The first two rows in Plate V show the sediment test and bacterial count of samples of milk at each morning's milking, the lower two rows the results from the night's milking. At the beginning, when conditions were fairly clean, it will be noted that there was a little sediment and that the bacterial count was low. On each successive day, as the cows and barn floor became dirtier, the quantity of sediment gradually increased together with the bacterial count. There were slight fluctu-

ations in the quantity of sediment as well as in the bacterial count, but on the whole there was a strikingly close relation. Plate V shows that after the morning milking on October 22 there was a decided drop in the quantity of sediment as well as in the bacterial count. On that date the manure was removed from the stable in the afternoon. That night's milk showed decidedly less sediment and a lower bacterial count, as did also both milkings of October 23. The results show that there is some direct relation between the sediment and bacterial count which always may be influenced by the variable number of bacteria in the manure. It is therefore quite evident that the sediment test is of value only under certain conditions.

Bacterial counts shown in Plate V are particularly interesting since they show that a very large quantity of sediment, in other words, manure, is necessary to create high counts provided the principal source of contamination is manure. In the experiment in which the manure was not removed nor the cows cleaned for nine days, the highest count obtained was 1,550,000, and the next highest was 1,150,000 bacteria per cubic centimeter. The other counts ranged from 6,600 to 450,000 bacteria per cubic centimeter. After the manure was removed the experiment was repeated under similar conditions for 10 days. During the latter period the highest count obtained was 82,000 and the lowest 6,600. In both experiments sterilized utensils were used; consequently, the contamination was due principally to the introduction of manure into the milk. The figures indicate that counts above 200,000 per cubic centimeter in milk usually should not be attributed entirely to contamination from manure.

The number of bacteria in 57 samples of fresh cow manure was determined, and the results are shown in Table 16. The range in number of bacteria per gram was from 2,900,000 to 690,000,000, the average number per gram being 49,645,614. From these results it can be assumed, therefore, that the average bacterial content of fresh manure is about 50,000,000 per gram. From that number it is possible to calculate the number of bacteria added to each cubic centimeter of a pint of milk through contamination by definite quantities of manure. Table 17 shows the number of bacteria that would be added to each cubic centimeter of milk if fresh manure were added in quantities varying from 0.5 to 0.01 of a gram, assuming an average gram sample to contain 50,000,000 bacteria. The figures show that 0.5 gram of fresh manure would add 52,854 bacteria to each cubic centimeter of a pint of milk, while 0.01 of a gram of manure would add 1,057.

TABLE 16.—*Number of bacteria in fresh cow manure.*

Sample No.	Bacteria per gram.	Sample No.	Bacteria per gram.	Sample No.	Bacteria per gram.	Sample No.	Bacteria per gram.
1	14,500,000	16	12,000,000	31	6,200,000	46	6,800,000
2	51,000,000	17	60,000,000	32	5,800,000	47	9,400,000
3	3,500,000	18	4,000,000	33	7,800,000	48	71,000,000
4	12,000,000	19	15,000,000	34	6,960,000	49	38,700,000
5	40,000,000	20	120,000,000	35	41,000,000	50	17,200,000
6	8,000,000	21	11,000,000	36	88,000,000	51	41,000,000
7	52,000,000	22	8,000,000	37	14,500,000	52	60,000,000
8	23,300,000	23	40,000,000	38	11,000,000	53	10,400,000
9	650,000,000	24	9,000,000	39	55,000,000	54	8,700,000
10	53,000,000	25	7,500,000	40	5,000,000	55	3,200,000
11	15,000,000	26	30,000,000	41	32,000,000	56	2,900,000
12	160,000,000	27	9,500,000	42	13,000,000	57	11,500,000
13	30,000,000	28	27,300,000	43	40,000,000		
14	19,700,000	29	5,100,000	44	9,500,000	Average	49,645,614
15	690,000,000	30	6,000,000	45	26,300,000		

TABLE 17.—*Theoretical number of bacteria which may be added to milk by varying quantities of manure.*

Quantity of wet manure added to 1 pint of milk.	Number of bacteria added to each cubic centimeter of milk.
Gram.	
0.5	52,854
.4	42,283
.3	31,712
.2	21,141
.1	10,571
.075	7,907
.05	5,285
.025	2,642
.01	1,057

In order to show how much manure would be added to the milk, on the basis shown in Table 17, Plate VI shows a number of sediment disks.[1] It will be seen from the figure that 0.5 of a gram of wet manure represents a quantity far in excess of that found in milk as produced on an average farm, and by referring again to Table 17 it is evident that this excessive quantity of manure would add only 52,854 bacteria per cubic centimeter. If 0.1 of a gram of manure were added to a pint of milk, that quantity would add only 10,571 bacteria to each cubic centimeter.

It is realized, of course, that these figures are only relative because of the variation in the bacterial content of manure, and, furthermore, that which does enter the milk is not necessarily fresh. The figures, however, confirm former conclusions that manure, though an important source of contamination in general, is not so great a factor as unsterilized utensils in causing high bacterial counts.

[1] The authors are indebted to George B. Taylor, of the Dairy Division, for this series of disks showing definite quantities of fresh manure.

THE THREE MOST ESSENTIAL FACTORS IN THE PRODUCTION OF MILK OF LOW BACTERIAL CONTENT.

In connection with the term "production of milk" as used in this paper, it is evident that there are three essential factors which most influence the bacterial content. Named in the order of their importance they are, first, the use of sterilized utensils; second, clean cows, particularly the udders and teats; third, the use of the small-top pail. By the use of these factors it has been possible to produce milk of a low bacterial count and practically free from visible dirt in an experimental barn which represents a poor type found in this country. In fact, the counts obtained were so low that only 2,000 to 3,000 bacteria per cubic centimeter were introduced through external contamination. A large number of factors not considered in this paper are responsible for this contamination. Some of them have been extensively studied by Stocking (1), Harding (9), Ruehle (10), and Prucha (11).

It is evident, therefore, that the three simple factors mentioned prevent most of the contamination of milk. It is possible, however, that under some circumstances low-count milk can not be produced by means of these few factors. It has been shown that they prevent most of the external contamination and that by their use it is possible to produce milk with a bacterial content very nearly as low as that drawn directly from the udder. If milk drawn directly from the udder is high in bacteria, it is impossible under any conditions to produce a low-count milk.

It is well known that freshly drawn milk from some cows is sometimes high in bacteria; if there are, therefore, a number of such cows in a herd, the bacterial content of the mixed milk will be relatively high. As an example it may be well to mention a case in which milk produced in a sanitary barn from clean cows and with sterilized utensils averaged 5,096 bacteria per cubic centimeter for 28 samples. In the herd there were cows whose milk occasionally was abnormal, in that it contained a few small clots and the last milk sometimes was slightly stringy. The milk from these cows was kept separate from the regular herd milk, with the result that 28 samples of it, produced at the same time as the other samples, averaged 137,786 bacteria per cubic centimeter. It is therefore evident that with cows of that type it would be impossible under any conditions to produce a low-count milk.

It is not known how common such cows are in this country, and the point is mentioned merely to show why it is sometimes impossible, even with the three essential factors, to produce milk of low bacterial count.

The criticism may be raised that the value of the essential factors was determined under experimental conditions which do not repre-

sent practical conditions on the farm; therefore the following experiment was conducted under actual farm conditions to determine their value when used by the average dairyman.

A PRACTICAL DEMONSTRATION ON SIX FARMS.

In order to demonstrate the practical value of the three essential factors previously mentioned they were applied on six farms in the vicinity of Grove City, Pa., with the voluntary cooperation of the dairymen. Five of the farms sent milk and one sent cream to the experimental creamery operated at Grove City by the Dairy Division. It seemed advisable to have one producer of cream, in order to determine whether these factors would improve its quality.

FIG. 17.—Interior of barn at farm No. 1.

The scores of the six farms, according to the dairy-farm score card used by the Dairy Division, United States Department of Agriculture, were as follows: 44.1, 42, 40.5, 41.1, 40.9, and 38.4 out of a possible 100. The interiors of the barns are shown in figures 17 to 21, inclusive. The plan was to determine, first, the bacterial content of the fresh milk and cream on the farm under the existing conditions; then to place in operation the three factors, namely, sterilized utensils, clean cows with clean udders and teats, and small-top pails.

FIG. 18.—Interior of barn at farm No. 20.

For the work small-top pails of the type shown in figure 2 were lent to the farmers, together with simple steam sterilizers which are described in Farmers' Bulletin 748. The method of operating the

sterilizer was demonstrated to the farmers, who were then left to operate it without further assistance. As the work was carried on during the summer and the cows were in pasture most of the time, their udders were always practically free from visible dirt; therefore that factor received no further consideration.

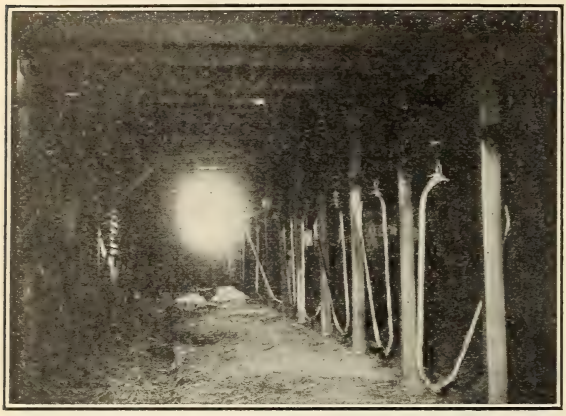


FIG. 19.—Interior of barn at farm No. 27.

At each milking the milk was stirred by means of a long, sterile pipette, after which samples were taken from each can and a composite sample made, which was immediately placed in ice water and plated within an hour and a half. For a period of three weeks samples were taken at each farm under the usual conditions (open pails, not sterilized) and for the three weeks following, when small-top pails, sterilized, were in operation.

Table 18 shows the bacterial count of each sample obtained from the night's milk, fresh, on each farm during the entire six weeks, also

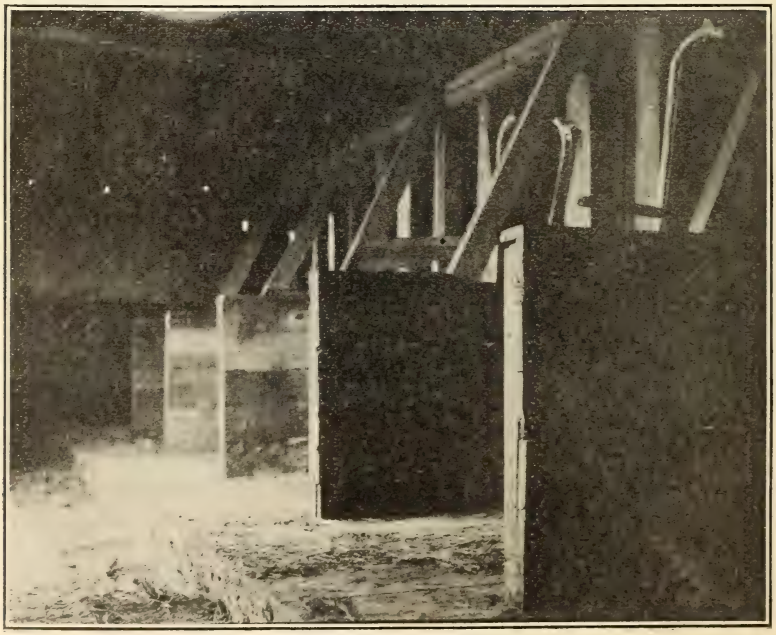


FIG. 20.—Interior of barn at farm No. 43.

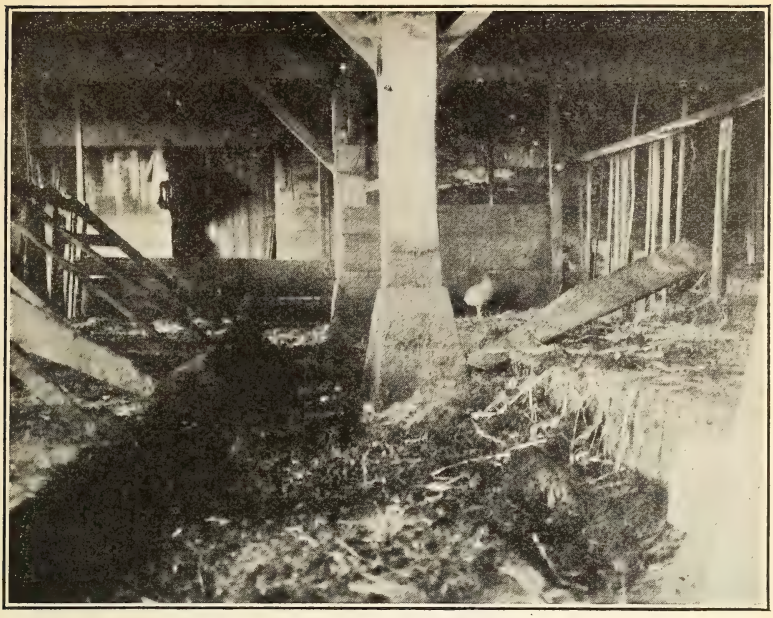


FIG. 21.—Interior of barn at farm No. 178.

the average counts. Figure 22 shows graphically the summarized and average results of the series of samples from each farm before and after the three essential factors were introduced. It will be noted that among the six farms some produced milk of a relatively low bacterial content. Milk produced from farms 20 and 43 under the ordinary conditions showed, respectively, average counts of 15,050 and 34,861 bacteria per cubic centimeter, while after the introduction of the three essential factors the count was reduced to 4,656 and 2,050, respectively. The greatest average decrease due to the intro-

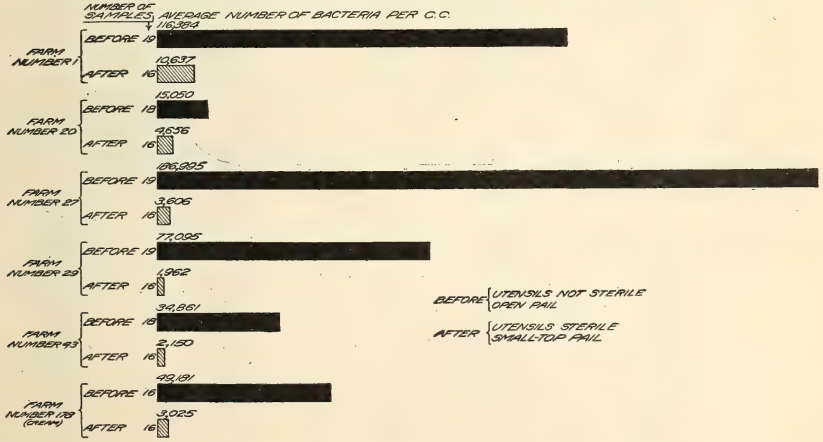


FIG. 22.—Average bacterial content of night's milk, produced on farms near Grove City, Pa., before and after using the three most essential factors for the production of milk of low bacterial content.

duction of the essential factors was noted on farm 27, where the average count was reduced from 186,995 to 3,606 bacteria per cubic centimeter. On farm 178 the average number of bacteria in the cream was reduced from 49,181 to 3,025 per cubic centimeter; all the separator parts were sterilized in the simple steam sterilizer and held in it until ready for use.

TABLE 18.—*Bacteria per cubic centimeter in daily samples of milk (5 farms) and cream (1 farm), showing effect of using small-top pails and sterilized utensils.*

Farm No.	Open pails, utensils not sterilized (3 weeks, July 23 to Aug. 12).	Small-top pails, utensils sterilized (3 weeks, Aug. 15 to Sept. 2).	Farm No.	Open pails, utensils not sterilized (3 weeks, July 23 to Aug. 12).	Small-top pails utensils sterilized (3 weeks, Aug. 15 to Sept. 2).
1	233,000	3,500	29	80,000	1,200
	81,000	2,700		109,000	600
	103,000	51,300		65,000	1,700
	176,000	8,500		8,000	1,100
	67,000	3,200		16,200	900
	220,000	4,100		80,000	3,150
	17,300	4,500		8,500	2,800
	139,000	10,000		25,300	1,300
	15,200	4,100		302,000	1,700
	16,900	5,000		19,000	1,750
	28,500	30,000		400,000	1,300
	49,000	10,000		30,000	2,200
	212,000	7,600		44,800	1,100
	49,000	9,000		6,000	7,000
	88,000	10,800		140,000	2,300
	32,300	5,900		11,000	1,300
	600,000			100,000	
	12,600			10,600	
	71,000			9,400	
	Average of 19 samples, 116,384.	Average of 16 samples, 10,637.		Average of 19 samples, 77,095.	Average of 16 samples, 1,962.
20	10,300	3,100	43	4,200	1,100
	143,000	800		70,000	900
	7,000	5,400		320,000	2,000
	5,800	2,900		64,000	1,700
	12,000	700		6,600	2,700
	1,200	3,800		2,000	5,600
	5,300	3,300		9,700	1,700
	17,400	4,500		2,600	5,600
	3,300	2,700		6,000	2,550
	3,200	2,550		6,000	2,050
	5,400	2,050		16,000	2,200
	6,200	26,100		30,000	1,700
	20,000	2,800		64,000	1,600
	9,700	2,700		11,400	1,100
	5,000	800		3,600	1,000
	6,700	10,300		4,600	900
	5,200			4,000	
	4,200			2,800	
	Average of 18 samples, 15,050.	Average of 16 samples, 4,656.		Average of 18 samples, 34,861. Average of 93 samples, 87,391.	Average of 16 samples, 2,150. Average of 80 samples, 4,602.
27	420,000	2,300			
	134,000	1,600			
	91,000	3,100	178 (cream).	12,000	2,100
	47,000	2,400		6,000	100
	155,000	1,400		52,000	2,200
	93,000	4,000		15,000	1,300
	77,000	1,900		2,400	4,200
	188,000	1,800		15,500	2,250
	118,000	1,800		17,400	3,400
	102,000	24,000		3,200	3,700
	44,200	2,300		7,200	10,000
	406,000	1,500		24,700	750
	140,000	2,800		35,700	2,000
	1,140,000	2,500		94,000	3,600
	92,000	2,000		300,000	2,600
	34,400	2,300		8,000	2,400
	13,300			173,000	3,300
	105,000			20,800	4,500
	153,000				
	Average of 19 samples, 186,995.	Average of 16 samples, 3,606.		Average of 16 samples, 49,181.	Average of 16 samples, 3,025.

The average bacterial count of 93 samples of milk taken from the five farms under the ordinary conditions was 87,391 per cubic centimeter, which was reduced to 4,602 after the introduction of the three essential factors. The highest average bacterial count in fresh milk after the introduction of these factors was 10,637 and the lowest 1,962 per cubic centimeter.

It is believed that the results offer proof of the practical value of the three essential factors, namely, sterilized utensils, clean cows with clean udders and teats, and the use of small-top pails, for the production of milk of low bacterial count when fresh, on the average farm. The effect of holding the milk on the farm was not considered in this work.

BACTERIAL COUNTS OF FRESH MILK ON THE AVERAGE FARM.

One of the interesting points noted throughout this work was the fact that very high bacterial counts were not obtained, even under extremely dirty barn conditions, with dirty cows, and unsterilized utensils. As a rule, samples of fresh milk taken directly after milking, when produced under these conditions, contained less than 1,000,000 and usually below 500,000 bacteria per cubic centimeter. It must be remembered that in this work fresh milk which had not been strained or cooled was examined. It is realized, of course, that straining and cooling over unsterilized coolers would increase the bacterial count to some extent. This observation led to the belief that in all probability the bacterial count of fresh milk as produced on the average farm is not so high as has been generally believed.

In order to obtain some information on this point, 249 samples of fresh milk from 12 different farms around Grove City, Pa., were examined during the summer of 1916. The milk was strained but not cooled. The condition of the barns and the methods of handling milk probably represent the average on uninspected farms in the North and North Central part of this country and would score on the average approximately 40 points out of a possible 100, based on the United States Department of Agriculture dairy-farm score card.

The results of the examination of samples of morning's and night's milk are shown in Table 19. The night's samples averaged 115,135, and the morning's samples averaged 180,696 bacteria per cubic centimeter, and the average for all was 135,146.

TABLE 19.—*The bacterial content of 249 samples of fresh milk as produced on 12 farms.*

Farm No.	Bacteria per c. c.	Farm No.	Bacteria per c. c.	Farm No.	Bacteria per c. c.	Farm No.	Bacteria per c. c.	Farm No.	Bacteria per c. c.
1	233,000	14	119,000	20	10,300	27	20,000	43	2,000
	81,000		130,000		143,000		42,000		9,700
	103,000		190,000		7,000		92,000		2,600
	176,000		290,000		5,800		[1] 130,000		6,000
	67,000		90,000		12,000		[1] 242,000		6,000
	220,000		64,000		1,200		[1] 36,000		16,000
	17,300		1,250,000		5,300		[1] 4,000		30,000
	139,000		[1] 505,000		17,400		[1] 26,000		64,000
	15,200		[1] 400,000		3,300		[1] 250,000		11,400
	16,900		[1] 660,000		3,200		[1] 16,000		3,600
	28,500		[1] 145,000		5,400		[1] 20,000		4,600
	49,000		[1] 820,000		6,200		[1] 64,000		4,000
	212,000		[1] 21,000		20,000				2,800
	49,000		[1] 168,000		9,700		80,000		
	88,000		[1] 230,000		5,000	29	109,000	47	13,000
	32,800		[1] 470,000		6,700		65,000		42,000
	600,000		[1] 121,000		5,200		8,000		15,000
	12,600		[1] 2,270,000		4,200		16,200		19,000
	71,000		[1] 1,890,000				80,000		2,970,000
	110,000		[1] 230,000	23	240,000		8,500		[1] 16,000
	4,000		[1] 1,020,000		400,000		25,300		[1] 6,000
	10,000	16			112,000		302,000		[1] 55,000
	13,000		29,400		65,000		19,000		[1] 6,000
	60,000		25,000		170,000		400,000		[1] 32,000
	[1] 26,900		20,000		[1] 145,000		30,000		[1] 33,000
	[1] 222,000		13,000		[1] 490,000		44,800		
	[1] 26,000		22,000		[1] 233,000		6,000	78	49,000
	[1] 27,000		14,000		[1] 300,000		140,000		70,000
	[1] 33,000		4,000		[1] 63,000		11,000		180,000
	[1] 100,000		14,000		[1] 37,000		100,000		35,000
	[1] 54,000		40,000				10,600		75,000
	[1] 36,000		27,000	27	420,000		9,400		62,000
	[1] 56,000		95,000		134,000		6,000		24,000
			450,000		91,000		17,000		45,000
5	147,000		24,000		47,000		50,000		12,000
	474,000		[1] 480,000		155,000		8,000		23,000
	92,000		462,000		93,000		220,000		136,000
	127,000		[1] 41,000		77,000		[1] 54,000		85,000
	173,000		[1] 29,000		188,000		[1] 34,000		360,000
	110,000		[1] 22,000		118,000		[1] 6,000		[1] 50,000
	34,000	17			102,000		[1] 15,000		[1] 153,000
	20,000		30,000		44,200		[1] 14,000		[1] 58,000
	39,700		21,000		406,000		[1] 114,000		[1] 29,000
	26,000		20,000		140,000		[1] 27,000		[1] 24,000
			78,000		1,140,000		[1] 40,000		[1] 38,000
14	219,000		84,000		92,000		[1] 170,000		[1] 10,000
	445,000		[1] 40,000		34,400				[1] 34,000
	237,000		[1] 4,000		13,300		4,200		[1] 80,000
	205,000		[1] 11,000		105,000	43	70,000		[1] 77,000
	204,000		[1] 98,000		153,000		320,000		[1] 66,000
	69,000		[1] 33,000		82,000		64,000		[1] 51,000
	46,000		[1] 34,000		44,000		6,600		

[1] Morning's milk.

Average of all samples, 249, taken on 12 farms was 135,146 bacteria per cubic centimeter.
Average of 173 samples of night's milk taken on 12 farms was 115,135 bacteria per cubic centimeter.
Average of 76 samples of morning's milk taken on 9 farms was 180,696 bacteria per cubic centimeter.

The samples may be grouped according to the number of bacteria per cubic centimeter, as follows:

	Samples.
1,000,001 or more	6
500,001 to 1,000,000	4
250,001 to 500,000	16
100,001 to 250,000	49
50,001 to 100,000	44
50,000 or below	130
Total	249

These figures indicate that the presence of millions of bacteria in milk, which in the past have been considered to a large extent as

evidence of great contamination, is evidently not due in most cases to original contamination. The results show that extremely high counts in milk are in general the result of bacterial growth rather than original contamination.

THE EFFECT OF TEMPERATURE ON THE GROWTH OF BACTERIA IN MILK.

The results shown in the previous discussion of the factors essential for the production of milk of low bacterial count when fresh apply only to fresh milk. The dairyman must remember that when milk of that kind has been produced his responsibility has not ended, for the milk must be kept cold to prevent the growth of bacteria. The three factors discussed prevent to a large degree the contamination of milk during production, as the term is used in this bulletin. In the broad sense of the term "production of milk," the effect of temperature at which the milk is held on the farm must also be considered. It is one of the greatest problems in the handling of milk on the farm, and extensive studies have been made to show the effect of holding milk at different temperatures during varying lengths of time. Samples of milk produced under different conditions were held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.) and examined when fresh and after each interval of 24 hours for 96 hours, or 4 days. The milk was produced in the experimental barn under three different sets of conditions, as follows:

First. Cows were clean and bedded; the udders washed part of the time and left unwashed part of the time; the small-top pail used; and all utensils were sterilized.

Second. Cows were dirty; the manure was removed twice a week; both open and small-top pails used; and all utensils were sterilized.

Third. Conditions same as second except that the utensils were not sterilized.

Complete detailed results showing the growth of the bacteria in the milk produced under the different conditions mentioned are given. Twenty samples produced under condition 1 were studied; 34 samples under condition 2, and 30 under condition 3.

The bacterial development in milk having a low count, as described under the first condition, is shown in Table 20. The calculated ratio of the bacterial growth in each sample is shown in Table 21. The bacterial development in milk under the second condition mentioned is shown in Table 22 and the ratio of the bacterial development in Table 23. Tables 24 and 25 show similar results for milk produced under the third condition. The summary of the averages of all the samples studied during this work is shown in Table 26. It will be noted that the milk produced under the three conditions when fresh showed somewhat different bacterial counts; that produced under condition 1 averaged 4,295 bacteria per cubic centimeter; under condition 2, 39,082; and under condition 3, 136,533. It will be seen,

therefore, that three different grades of milk, based on their bacterial counts, were considered.

The figures presented in the tables show that with two samples of approximately the same initial bacterial count the increase was not always at exactly the same rate. In some determinations there were occasional counts far above normal at given periods, which can be explained by the fact that there may have been a slight variation in bacterial types, although the initial count was approximately the same. One type may have grown more rapidly at a certain temperature than the types in other samples. It is believed, however, that in this work the variations above the normal were due to inability to control absolutely the temperatures in the holding boxes. In general, however, the variations had little or no effect upon the average counts for the entire series of samples studied.

In Table 26 the average results have been grouped in two different ways; first, to show the growth of bacteria in a series of samples produced under the three conditions and having different initial counts, when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.), respectively; second, to show the growth of bacteria in each grade of milk when held at the same temperatures. In the lower part of the table are shown the average ratios of bacterial growth arranged to correspond to the counts in the upper portion. The ratios were obtained by dividing the count, after each successive period of 24 hours, by the initial count.

In the sample held at 4.4° C. (40° F.) there was a relatively small growth of bacteria during the period of 96 hours. A most interesting effect of temperature on the growth of bacteria is shown by the samples of milk produced under the third condition and held at 10° C. (50° F.). It will be seen that when milk with an average count of 4,295 was held for 72 hours, the average count was but little higher than that of milk with an original count of 136,553 per cubic centimeter held 24 hours at the same temperature. A similar condition was found also among samples of low-count milk held 48 hours at 15.5° C. (60° F.), which showed a count of approximately 33,000,000 bacteria, while high-count milk reached approximately 24,000,000 in 24 hours. At the end of 96 hours the bacterial growth reaches a point where the counts are so high as to be approximately the same for all grades of milk.

It is evident that the development of bacteria in different grades of milk at 10° C. (50° F.) has a direct practical bearing. For example, if milk were produced on a farm under conditions[1] which when fresh averaged approximately 4,000 bacteria per cubic centimeter, when held at 10° C. (50° F.) for 48 hours it would contain an average of approximately 127,000. If milk were produced under

[1] Morning's milk.

condition 3, which when fresh averaged approximately 136,000 bacteria per cubic centimeter, when held for 48 hours at 10° C. (50° F.) its average count would be approximately 13,000,000. The difference in count would be of great importance if an attempt were being made to market a milk of low bacterial content.

TABLE 20.—*Growth of bacteria in milk produced under condition 1 when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.).*

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	4.4° C. (40° F.).	3,500	2,500	3,300	14,400	21,100
2		6,900	7,700	7,300	8,900	13,100
3		3,400	3,700	3,800	4,100	3,400
4		7,400	7,100	6,200	4,100	3,500
5		4,700	5,900	5,300	4,200	16,000
6		5,300	3,300	2,900	11,600	.....
7		7,300	5,300	4,500	.....	8,500
8		3,300	4,200	.....	3,400	7,600
9		9,400	.....	11,400	11,800	21,000
10		3,900	4,100	3,900	5,400	.....
11		3,900	7,400	5,300	10,100	18,200
12		4,200	3,500	4,700	9,300	22,600
13		4,700	4,300	4,800	5,200	6,500
14		1,600	2,300	2,500	3,800	23,400
15		3,400	3,800	6,900	40,500	109,000
16		2,200	2,400	2,300	2,200	.....
17		2,900	2,600	3,200	.....	21,000
18		1,400	1,700	.....	6,100	18,000
19		3,400	.....	1,600	2,500	2,200
20		2,100	2,700	2,300	4,100	.....
Average		4,295	4,138	4,566	8,427	19,693
1	10° C. (50° F.).	3,500	6,400	8,200	4,500,000	34,800,000
2		6,900	14,400	55,600	3,760,000	96,000,000
3		3,400	5,800	26,000	570,000	13,300,000
4		7,400	8,900	35,000	260,000	19,300,000
5		4,700	10,800	33,000	8,700,000	43,500,000
6		5,300	6,100	510,000	6,400,000	.....
7		7,300	5,100	22,000	.....	6,700,000
8		3,300	4,700	.....	180,000	.....
9		9,400	.....	28,000	90,000	4,100,000
10		3,900	5,900	18,500	1,440,000	.....
11		3,900	8,100	7,200	5,100,000	95,000,000
12		4,200	41,200	900,000	39,000,000	212,000,000
13		4,700	20,200	205,000	1,260,000	14,200,000
14		1,600	18,200	71,000	1,150,000	20,200,000
15		3,400	65,000	280,000	31,000,000	55,000,000
16		2,200	5,200	13,600	190,000	.....
17		2,900	12,700	42,000	.....	12,200,000
18		1,400	6,400	.....	190,000	1,400,000
19		3,400	.....	28,000	95,000	3,600,000
20		2,100	6,200	16,000	170,000	.....
Average		4,295	13,961	127,727	5,725,277	39,490,625
1	15.5° C. (60° F.).	3,500	1,250,000	74,000,000	265,000,000	4,240,000,000
2		6,900	1,300,000	42,500,000	170,000,000	.....
3		3,400	160,000	13,200,000	87,000,000	208,000,000
4		7,400	156,000	20,600,000	172,000,000	1,180,000,000
5		4,700	10,200,000	31,800,000	1,550,000,000	2,100,000,000
6		5,300	1,010,000	28,200,000	242,000,000	.....
7		7,300	310,000	18,900,000	.....	149,000,000
8		3,300	55,000	.....	74,000,000	106,000,000
9		9,400	.....	5,800,000	71,000,000	152,000,000
10		3,900	270,000	14,800,000	248,000,000	.....
11		3,900	1,220,000	63,000,000	750,000,000	910,000,000
12		4,200	1,580,000	85,000,000	1,640,000,000	.....
13		4,700	240,000	23,100,000	112,000,000	276,000,000
14		1,600	74,000	17,300,000	22,000,000	1,490,000,000
15		3,400	10,100,000	97,100,000	152,000,000	2,040,000,000
16		2,200	102,000	24,900,000	112,000,000	.....
17		2,900	110,000	14,500,000	.....	270,000,000
18		1,400	105,000	.....	59,000,000	157,000,000
19		3,400	.....	7,900,000	64,000,000	201,000,000
20		2,100	330,000	11,600,000	87,000,000	.....
Average		4,295	1,587,333	33,011,111	326,500,000	962,785,714

TABLE 21.—*Ratio of bacterial growth in milk produced under condition 1 when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.).*

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	4.4° C. (40° F.).	1	[1] 0	0	4.11	6.02
2		1	1.11	1.05	1.28	1.89
3		1	1.08	1.09	1.20	1
4		1	0	0	0	0
5		1	1.25	1.12	0	3.40
6		1	0	0	2.18	.....
7		1	0	0	.....	1.16
8		1	1.27	.....	1.03	2.30
9		1	.....	1.21	1.25	2.23
10		1	1.05	1	1.38	.....
11		1	1.89	1.35	2.58	4.66
12		1	0	1.11	2.21	5.38
13		1	0	1.02	1.10	1.38
14		1	1.43	1.56	2.37	1.46
15		1	1.11	2.02	11.91	32.05
16		1	1.09	1.04	1	.....
17		1	0	1.10	.....	7.24
18		1	1.21	.....	4.35	1.28
19		1	.....	0	0	0
20		1	1.28	1.09	1.95	.....
Average			1.25	1.21	2.66	5.10
1	10° C. (50° F.).	1	1.82	2.34	1,285.7	9,942.8
2		1	2.08	8.05	544.9	13,913
3		1	1.70	7.64	167.6	3,911.7
4		1	1.20	4.72	35.1	2,608.1
5		1	2.29	7.02	1,851	9,255.3
6		1	1.15	96.20	1,018.8	.....
7		1	0	3.01	.....	917.8
8		1	1.42	.....	54.5	166.6
9		1	.....	2.97	9.5	436 1
10		1	1.51	4.74	369.2	.....
11		1	2.07	1.84	1,307.6	24,358.9
12		1	9.80	214.20	9,285.7	50,476.1
13		1	4.29	43.60	268	3,021.2
14		1	11.37	44.30	718.7	12,625
15		1	1.91	82.30	9,117.6	16,176.4
16		1	2.36	6.18	86.3	.....
17		1	4.37	14.40	.....	4,206.8
18		1	4.57	.....	135.7	1,000
19		1	.....	8.23	27.9	1,058.8
20		1	2.95	7.61	80.9	.....
Average			3.34	31.07	1,464.7	9,629.6
1	15.5° C. (60° F.).	1	357.1	21,142.8	75,714.2	1,211,428.5
2		1	188.4	6,159.4	24,637.6	.....
3		1	47	3,882.3	25,588.2	61,176.4
4		1	21	2,783.7	23,243.2	159,459.4
5		1	2,170.2	6,765.9	329,787.2	446,808.5
6		1	190.5	5,320.7	45,660.9	.....
7		1	42.4	2,589	.....	20,410.9
8		1	16.6	.....	22,424.2	32,121.2
9		1	.....	617	7,553.1	16,170.2
10		1	69.2	3,794.8	63,589.7	.....
11		1	312.8	16,153.8	192,307.6	233,333.3
12		1	376.1	20,238	390,476.1	.....
13		1	51	4,914.8	23,829.7	58,723.4
14		1	46.2	10,812.5	13,750	931,250
15		1	2,970.5	28,558.8	44,705.8	600,000
16		1	46.3	11,318.1	50,909	.....
17		1	37.9	5,000	.....	93,103.4
18		1	75	.....	42,142.8	112,142.8
19		1	.....	2,323.5	18,823.5	59,117.6
20		1	157.1	5,523.8	41,428.5	.....
Average			398.6	8,772.1	79,809.5	288,231.8

[1] Bacterial count less than initial count.

TABLE 22.—*Growth of bacteria in milk produced under condition 2 when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.).*

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	4.4° C. (40° F.)	10,600	11,600	19,000	.....	508,000
2		8,100	14,500	.....	14,800	.....
3		13,900	.....	14,100	.....	35,000
4		165,000	176,000	.....	254,000	660,000
5		240,000	.....	370,000	540,000	480,000
6		83,000	290,000	.....	1,560,000	3,050,000
7		65,000	240,000	300,000	410,000	.....
8		121,000	890,000	970,000	.....	.....
9		16,500	29,800	20,100	37,000	26,000
10		19,600	39,300	35,600	23,000	.....
11		69,000	65,000	448,000	.....	15,300,000
12		66,000	72,000	.....	98,000	156,000
13		53,000	.....	199,000	470,000	620,000
14		8,900	11,500	17,700	24,000	29,000
15		16,100	13,400	34,000	28,000	.....
16		4,100	7,900	8,200	.....	4,100
17		65,000	82,000	.....	217,000	1,800,000
18		4,300	4,400	5,500	.....	38,000
19		5,600	13,700	.....	11,800	.....
20		10,800	.....	9,600	.....	32,000
21		26,900	29,500	.....	46,000	67,000
22		29,800	.....	74,000	77,000	.....
23		14,600	111,000	371,000	355,000	115,000
24		19,700	79,000	141,000	106,000	.....
25		78,000	99,000	176,000	.....	.....
26		3,200	2,800	2,900	2,700	2,500
27		7,500	14,800	22,300	14,500	.....
28		7,200	23,300	26,000	.....	220,000
29		17,700	45,000	.....	58,000	.....
30		31,000	.....	68,000	37,000	34,000
31		6,100	20,400	17,800	17,500	13,200
32		10,200	9,800	18,600	19,600	.....
33		8,400	10,100	11,200	.....	4,500
34		23,000	59,000	.....	49,000	58,000
Average	.....	39,082	88,028	121,864	186,245	1,056,922
1	10° C. (50° F.)	10,600	68,000	270,000	.....	8,100,000
2		8,100	137,000	.....	330,000	.....
3		13,900	.....	85,000	.....	4,400,000
4		165,000	382,000	.....	1,700,000	6,800,000
5		240,000	.....	910,000	1,400,000	2,800,000
6		83,000	860,000	3,100,000	5,900,000	24,500,000
7		65,000	.....	380,000	850,000	.....
8		121,000	960,000	1,190,000	.....	.....
9		16,500	83,000	389,000	580,000	20,400,000
10		19,600	51,000	76,000	6,060,000	.....
11		69,000	321,000	9,800,000	.....	82,000,000
12		66,000	181,000	.....	800,000	63,000,000
13		53,000	.....	1,100,000	2,400,000	5,200,000
14		8,900	42,000	112,000	250,000	8,800,000
15		16,100	37,000	630,000	320,000	.....
16		4,100	18,500	240,000	.....	2,900,000
17		65,000	116,000	.....	9,100,000	26,700,000
18		4,300	65,000	252,000	.....	4,700,000
19		5,600	53,000	.....	2,970,000	.....
20		10,800	.....	81,000	.....	900,000
21		26,900	123,000	.....	250,000	1,100,000
22		29,800	.....	130,000	350,000	380,000
23		14,600	348,000	1,080,000	4,600,000	3,900,000
24		19,700	176,000	340,000	810,000	.....
25		78,000	172,000	740,000	.....	.....
26		3,200	5,500	11,000	120,000	3,600,000
27		7,500	43,000	167,000	1,900,000	.....
28		7,200	78,000	250,000	.....	29,600,000
29		17,700	116,000	.....	570,000	3,900,000
30		31,000	.....	210,000	430,000	550,000
31		6,100	23,000	11,000	45,000	3,200,000
32		10,200	47,000	42,000	120,000	.....
33		8,400	12,800	26,000	.....	220,000
34		23,000	272,000	.....	420,000	1,300,000
Average	.....	39,082	177,437	831,615	1,761,458	13,079,166

TABLE 22.—*Growth of bacteria in milk produced under conditions 2 when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.)*—Continued.

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	15.5° C. (60° F.)	10,600	1,100,000	35,300,000	.....	142,000,000
2		8,100	2,100,000	.....	92,000,000	.....
3		13,900	.....	9,600,000	.....	990,000,000
4		165,000	4,900,000	.....	390,000,000	2,610,000,000
5		240,000	.....	126,000,000	1,690,000,000	1,820,000,000
6		81,000	.....	112,000,000	3,470,000,000	2,320,000,000
7		65,000	7,200,000	366,000,000	2,280,000,000	.....
8		121,000	4,400,000	339,000,000	.....	.....
9		16,500	3,080,000	53,200,000	108,000,000	1,370,000,000
10		19,600	720,000	33,400,000	670,000,000	.....
11		69,000	8,900,000	203,000,000	.....	.....
12		66,000	14,800,000	.....	270,000,000	980,000,000
13		53,000	.....	190,000,000	210,000,000	.....
14		8,900	1,870,000	22,800,000	1,200,000,000	2,070,000,000
15		16,100	6,400,000	226,000,000	560,000,000	.....
16		4,100	2,400,000	152,000,000	.....	830,000,000
17		65,000	4,500,000	.....	630,000,000	5,500,000,000
18		4,300	1,200,000	11,600,000	.....	135,000,000
19		5,600	1,700,000	.....	42,000,000	.....
20		10,800	.....	8,200,000	.....	1,280,000,000
21		26,900	3,600,000	.....	180,000,000	1,340,000,000
22		29,800	.....	12,600,000	190,000,000	970,000,000
23		14,600	6,100,000	22,000,000	340,000,000	376,000,000
24		19,700	17,700,000	61,000,000	524,000,000	.....
25		78,000	5,200,000	34,600,000	.....	.....
26		3,200	140,000	9,700,000	45,000,000	690,000,000
27		7,500	5,300,000	19,300,000	520,000,000	.....
28		7,200	2,150,000	158,000,000	.....	.....
29		17,700	2,100,000	.....	180,000,000	1,210,000,000
30		31,000	.....	84,000,000	320,000,000	600,000,000
31		6,100	1,190,000	19,500,000	140,000,000	780,000,000
32		10,200	3,300,000	164,000,000	490,000,000	.....
33		8,400	3,300,000	177,000,000	.....	340,000,000
34		23,000	5,100,000,	.....	660,000,000	1,590,000,000
Average		39,082	4,461,111	99,120,000	633,375,000	1,355,650,000

TABLE 23.—*Ratio of bacterial growth in milk produced under condition 2 when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.).*

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	4.4° C. (40° F.)	1	1.1	1.8	.....	47.9
2		1	1.7	.....	1.8	.....
3		1	.....	1.1	.....	2.5
4		1	1.1	.....	1.5	4
5		1	.....	1.5	2.2	2
6		1	3.5	.....	18.7	36.7
7		1	3.6	4.6	6.3	.....
8		1	7.3	8	.....	.....
9		1	1.8	1.2	2.2	1.6
10		1	2	1.8	1.2	.....
11		1	10	6.5	.....	221.7
12		1	1.1	.....	1.5	2.4
13		1	.....	3.7	8.8	11.7
14		1	1.3	1.9	2.7	3.2
15		1	0	2.1	1.7	.....
16		1	1.9	2	.....	0
17		1	1.3	.....	3.3	27.6
18		1	1.1	1.3	.....	8.8
19		1	2.4	.....	2.1	.....
20		1	.....	0	.....	2.9
21		1	1.1	.....	1.7	2.5
22		1	.....	2.5	2.6	.....
23		1	7.6	25.4	24.3	7.8
24		1	4	7.1	5.4	.....
25		1	1.3	2.2	.....	.....
26		1	0	0	0	0
27		1	1.9	2.9	1.9	.....
28		1	3.2	3.6	.....	30.5
29		1	2.5	.....	3.3	.....
30		1	.....	2.2	1.2	1.1
31		1	3.3	2.9	2.8	2.2
32		1	0	1.8	1.9	.....
33		1	1.2	1.3	.....	0
34		1	2.5	.....	2.1	2.5
Average		.....	2.4	3.8	4.4	22.1

TABLE 23.—*Ratio of bacterial growth in milk produced under condition 2 when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.)*—Continued.

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	10° C. (50° F.)	1	6.4	25.4	.....	764.1
2		1	16.9	.....	40.7	.....
3		1	.....	6.1	.....	316.5[1]
4		1	2.3	.....	10.3	41.2
5		1	.....	3.8	58.3	116.6
6		1	10.3	37.3	71	295.1
7		1	.....	5.8	13	.....
8		1	7.9	9.8	.....	.....
9		1	5	23.5	35.1	1,236.3
10		1	2.6	3.8	309.1	.....
11		1	4.6	142	.....	1,188.4
12		1	2.7	.....	12.1	954.5
13		1	.....	20.7	45.2	98.1
14		1	4.7	12.5	28	988.7
15		1	2.2	39.1	19.8	.....
16		1	4.5	58.5	.....	707.3
17		1	1.7	.....	140	410.7
18		1	15.1	58.6	.....	1,093.5
19		1	9.4	.....	530.3	.....
20		1	.....	7.5	.....	83.3
21		1	4.5	.....	9.3	40.9
22		1	.....	4.3	11.7	12.7
23		1	23.8	73.9	315	267.1
24		1	8.9	17.2	41.1	.....
25		1	2.2	9.4	.....	.....
26		1	1.7	3.4	37.5	1,125
27		1	5.7	22.2	253.3	.....
28		1	10.8	34.7	.....	4,111.1
29		1	6.5	.....	32.2	220.3
30		1	.....	6.7	13.8	17.7
31		1	3.7	1.8	7.3	524.5
32		1	4.6	4.1	11.7	.....
33		1	1.5	3.1	.....	26.2
34		1	11.8	.....	18.2	56.5
Average	.....	.....	6.7	24.3	86	612.3
1	15.5° C. (60° F.)	1	103.7	3,330.1	.....	13,396.2
2		1	259.2	.....	11,358	.....
3		1	.....	690.6	.....	71,223
4		1	29.6	.....	2,363.6	15,818.1
5		1	.....	525	7,041.6	7,583.3
6		1	.....	1,349.4	41,807.2	27,951.8
7		1	110.7	5,630.7	35,076.9	.....
8		1	36.4	2,801.6	.....	.....
9		1	186.6	3,224.2	6,545.4	83,030.3
10		1	36.7	1,704	34,183.6	.....
11		1	128.9	2,942	.....	.....
12		1	224.2	.....	4,090.9	14,848.4
13		1	.....	3,584.9	3,962.2	.....
14		1	210.1	2,561.7	134,831.3	232,584.2
15		1	397.5	14,037.2	34,782.6	.....
16		1	585.3	37,073.1	.....	202,439
17		1	69.2	.....	9,692.3	84,615.3
18		1	279	2,697.6	.....	31,395.3
19		1	303.5	.....	7,500	.....
20		1	.....	759.2	.....	118,518.5
21		1	133.8	.....	6,691.4	49,814.1
22		1	.....	422.8	6,375.8	32,550.3
23		1	417.8	1,506.8	23,287.6	25,753.4
24		1	898.4	3,096.4	26,598.9	.....
25		1	66.6	443.5	.....	.....
26		1	43.7	3,031.2	14,062.5	215,625
27		1	706.6	2,573.3	69,333.3	.....
28		1	298.6	21,944.4	.....	.....
29		1	118.6	.....	10,196.4	68,361.5
30		1	.....	2,709.6	10,322.5	19,354.8
31		1	195	3,196.7	22,950.8	127,868.8
32		1	323.5	16,078.4	48,039.2	.....
33		1	392.8	21,071.4	.....	40,476.2
34		1	221.7	.....	28,695.6	69,130.4
Average	.....	.....	351	6,114.8	24,990.1	73,920.8

[1] Bacterial count less than initial count.

TABLE 24.—*Growth of bacteria in milk produced under condition 3 when held at 4.4°, 10°, and 15.5° C. (40°, 50° and 60° F.).*

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	4.4° C. (40° F.)	149,000	262,000	354,000	386,000	620,000
2		9,200	8,200	15,600	63,000	9,500
3		22,500	39,000	41,000	60,000	.....
4		6,300	6,200	24,000	.....	135,000
5		6,800	12,200	.....	13,600	19,000
6		8,200	127,000	165,000	620,000	970,000
7		115,000	356,000	790,000	1,020,000	.....
8		207,000	290,000	252,000	.....	.....
9		216,000	1,440,000	2,700,000	3,550,000	3,840,000
10		202,000	600,000	720,000	910,000	2,700,000
11		332,000	278,000	266,000	407,000	.....
12		215,000	224,000	256,000	.....	250,000
13		209,000	207,000	.....	.....	.....
14		176,000	.....	.....	.....	260,000
15		256,000	.....	208,000	480,000	460,000
16		55,000	52,000	82,000	51,000	106,000
17		4,100	2,500	32,000	24,000	5,200
18		18,100	37,000	26,000	41,000	.....
19		11,400	15,700	38,000	.....	53,000
20		12,400	36,000	.....	35,000	68,000
21		193,000	313,000	295,000	540,000	596,000
22		169,000	243,000	510,000	530,000	.....
23		210,000	186,000	300,000	.....	.....
24		159,000	650,000	3,900,000	4,200,000	4,800,000
25		230,000	970,000	1,450,000	1,720,000	1,560,000
26		265,000	254,000	246,000	244,000	.....
27		168,000	158,000	162,000	.....	195,000
28		157,000	106,000	.....	.....	.....
29		186,000	.....	.....	.....	240,000
30		128,000	.....	98,000	86,000	170,000
Average		136,533	281,646	538,775	749,030	852,835
1	10° C. (50° F.)	149,000	380,000	1,770,000	7,900,000	48,000,000
2		9,200	37,000	510,000	126,000	3,600,000
3		22,500	107,000	2,080,000	34,800,000	.....
4		6,300	38,000	490,000	.....	8,600,000
5		6,800	91,000	.....	11,700,000	39,400,000
6		8,200	1,540,000	9,600,000	31,200,000	78,000,000
7		115,000	3,180,000	29,600,000	45,000,000	.....
8		207,000	1,560,000	16,800,000	.....	.....
9		216,000	2,400,000	53,000,000	65,000,000	96,000,000
10		202,000	1,490,000	35,600,000	31,000,000	33,900,000
11		332,000	4,200,000	14,300,000	26,300,000	.....
12		215,000	930,000	4,400,000	.....	34,200,000
13		209,000	840,000	.....	20,100,000	32,200,000
14		176,000	.....	9,500,000	24,200,000	36,500,000
15		256,000	2,040,000	27,500,000	20,100,000	15,600,000
16		55,000	47,000	260,000	220,000	18,400,000
17		4,100	4,300	35,000	55,000	560,000
18		18,100	43,000	490,000	8,900,000	.....
19		11,400	52,000	2,080,000	.....	58,000,000
20		12,400	394,000	.....	19,300,000	53,000,000
21		193,000	1,230,000	13,900,000	45,000,000	76,000,000
22		169,000	620,000	27,000,000	28,800,000	.....
23		210,000	560,000	5,700,000	.....	.....
24		159,000	2,700,000	42,000,000	68,000,000	110,000,000
25		230,000	2,180,000	24,700,000	33,600,000	34,900,000
26		265,000	1,210,000	9,100,000	25,200,000	.....
27		168,000	560,000	2,770,000	.....	41,300,000
28		157,000	240,000	.....	18,800,000	38,700,000
29		186,000	.....	4,630,000	26,700,000	23,400,000
30		128,000	1,060,000	17,400,000	22,700,000	26,300,000
Average		136,533	1,170,546	13,662,115	25,687,541	41,207,272

TABLE 24.—*Growth of bacteria in milk produced under condition 3 when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.)*—Continued.

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	15.5° C. (60° F.).	149,000	17,800,000	410,000,000	2,430,000,000	.....
2		9,200	2,900,000	218,000,000	160,000,000	.....
3		22,500	76,000,000	1,060,000,000	1,540,000,000	.....
4		6,300	4,700,000	255,000,000	.....	10,400,000,000
5		6,800	10,300,000	.....	1,110,000,000	1,640,000,000
6		8,200	32,300,000	125,000,000	910,000,000	2,230,000,000
7		115,000	22,600,000	198,000,000	1,650,000,000	.....
8		207,000	16,200,000	145,000,000	.....	.....
9		216,000	46,000,000	165,000,000	1,060,000,000	1,590,000,000
10		202,000	11,300,000	128,000,000	190,000,000	1,430,000,000
11		332,000	19,400,000	147,000,000	210,000,000	.....
12		215,000	9,700,000	126,000,000	.....	1,260,000,000
13		209,000	10,200,000	.....	1,160,000,000	8,300,000,000
14		176,000	.....	460,000,000	1,720,000,000	4,400,000,000
15		256,000	67,000,000	4,200,000,000	6,900,000,000	9,100,000,000
16		55,000	1,600,000	1,440,000,000	1,280,000,000	.....
17		4,100	510,000	1,050,000,000	3,000,000,000	.....
18		18,100	11,600,000	580,000,000	8,400,000,000	.....
19		11,400	88,000,000	1,800,000,000	.....	2,190,000,000
20		12.400	3,500,000	.....	4,400,000,000	1,750,000,000
21		193,000	72,000,000	411,000,000	4,900,000,000	5,400,000,000
22		169,000	11,900,000	373,000,000	3,140,000,000	.....
23		210,000	11,550,000	310,000,000	.....	.....
24		159,000	21,600,000	344,000,000	790,000,000	12,500,000,000
25		230,000	28,400,000	362,000,000	730,000,000	21,600,000,000
26		265,000	24,400,000	243,000,000	340,000,000	.....
27		168,000	7,100,000	87,000,000	.....	3,900,000,000
28		157,000	8,300,000	.....	1,970,000,000	4,600,000,000
29		186,000	.....	730,000,000	8,400,000,000	2,410,000,000
30		128,000	52,000,000	2,270,000,000	1,380,000,000	1,540,000,000
Average	.....	136,533	24,673,571	639,884,615	2,407,083,333	5,346,666,666

TABLE 25.—*Ratio of bacterial growth in milk produced under condition 3 when held at 4.4°, 10°, and 15.5° C., 40°, 50°, and 60° F.*

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	4.4° C. (40° F.)	1	1.75	2.37	2.59	4.16
2		1	[1] 0	1.69	6.84	1.03
3		1	1.73	1.82	2.66	.....
4		1	0	3.80	.....	21.40
5		1	1.79	.....	2	2.79
6		1	1.54	2.01	75.60	118.20
7		1	3.09	6.86	8.86	.....
8		1	1.40	1.21	.....	.....
9		1	6.66	12.50	16.40	17.70
10		1	2.97	3.56	4.50	13.30
11		1	0	0	1.22	.....
12		1	1.04	1.19	.....	1.16
13		1	0	.....	.....	.....
14		1	.....	.....	.....	1.47
15		1	.....	0	1.87	1.79
16		1	0	1.49	0	1.92
17		1	0	7.80	5.85	1.26
18		1	2.04	1.43	2.26	.....
19		1	1.37	3.33	.....	4.64
20		1	2.90	.....	2.82	5.48
21		1	1.62	1.52	2.79	3.08
22		1	1.43	3.01	3.13	.....
23		1	0	1.42	.....	.....
24		1	4.08	24.50	26.40	30.10
25		1	4.21	6.30	7.47	6.78
26		1	0	0	0	.....
27		1	0	0	.....	1.16
28		1	0	.....	.....	.....
29		1	.....	.....	.....	1.09
30		1	.....	0	0	1.32
Average	.....	.....	2.47	4.62	10.19	11.99

[1] Bacterial count less than initial count.

TABLE 25.—*Ratio of bacterial growth in milk produced under condition 3 when held at 4.4°, 10°, and 15.5° C. (40°, 50°, and 60° F.)*—Continued.

Sample No.	Temperature.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
1	10° C. (50° F.)	1	2.5	11.8	53.0	322.1
2		1	4	55.4	13.6	391.3
3		1	4.7	92.4	1,546.6	.....
4		1	6	77.7	.....	1,365
5		1	13.3	.....	1,720.5	5,794.1
6		1	187.8	1,170.7	3,804.8	9,512.1
7		1	27.6	257.6	391.3	.....
8		1	7.5	81.1	.....	.....
9		1	11.1	245.3	300.9	444.4
10		1	7.3	176.2	153.4	167.8
11		1	12.6	43	79.2	.....
12		1	4.3	20.4	.....	159
13		1	4	.....	96.1	154
14		1	.....	53.9	137.5	207.3
15		1	7.9	107.4	78.5	60.9
16		1	0	4.7	4	334 5
17		1	1.1	0	13.4	136.5
18		1	2.3	27	491.7	.....
19		1	4.5	182.4	.....	5,087.7
20		1	31.7	.....	1,556.4	4,274.1
21		1	6.3	72	233.1	393.7
22		1	3.6	159.7	170.4	.....
23		1	2.6	27.1	.....	.....
24		1	16.9	264.1	427.6	691.8
25		1	9.4	107.3	146	151.7
26		1	4.5	34.3	95	.....
27		1	3.3	16.4	.....	245.8
28		1	1.5	.....	119.7	246.4
29		1	.....	24.8	143.5	125.8
30		1	8.2	135.9	177.3	205.4
Average			14.6	137.9	498.1	1,385.1
1	15.5° C. (60° F.)	1	119.4	2,751.6	16,308.7	.....
2		1	315.2	23,695.6	17,391.3	.....
3		1	3,377.7	47,111.1	68,444.4	.....
4		1	746	40,476.1	.....	1,650,793.6
5		1	1,514.7	.....	163,235.2	241,176.4
6		1	3,939	15,243.9	110,975.6	271,951.2
7		1	196.5	1,721.7	14,347.8	.....
8		1	78.2	700.4	.....	.....
9		1	212.9	763.8	4,907.4	7,361.1
10		1	55.9	633.6	940.5	7,079.2
11		1	58.5	442.7	632.5	.....
12		1	45.1	586	.....	5,860.4
13		1	48.8	.....	5,550 2	39,712.9
14		1	.....	2,613.6	9,772.7	25,000
15		1	261.7	16,406.2	26,953.1	35,546.8
16		1	29	26,181.8	23.272.7	.....
17		1	124.3	256,097.5	731,707.3	.....
18		1	640.8	32,044.1	464,088.3	.....
19		1	7,719.2	157,894.7	.....	192,105.2
20		1	443.5	.....	354,838.7	141,129
21		1	373	2,129.5	25,388.6	27,979.2
22		1	70.4	2,207.1	18,520.7	.....
23		1	55	1,476.1	.....	.....
24		1	135.8	2,163.5	4,968.5	78,616.3
25		1	123.4	1,573.9	3,173.9	93,913
26		1	92	916.9	1,283	.....
27		1	42.2	517.8	.....	23,214.2
28		1	52.8	.....	12,547.7	29,299.3
29		1	.....	3,924.7	45,161.2	12,956.9
30		1	406.2	17,734.3	10,781.2	12,031.2
Average			759.9	25,308	61,527.2	160,873.6

TABLE 26.—*Summary of results shown in Tables 20 to 25 inclusive.*

AVERAGE NUMBER OF BACTERIA.

Temperature.	Condition.	Fresh.	24 hours.	48 hours.	72 hours.	96 hours.
SECTION 1.						
40° F.	1	4,295	4,138	4,566	8,427	19,693
	2	39,082	88,028	121,864	186,245	1,056,922
	3	136,533	281,646	538,775	749,030	852,835
50° F.	1	4,295	13,961	127,727	5,725,277	39,490,625
	2	39,082	177,437	831,615	1,761,458	13,079,166
	3	136,533	1,170,546	13,662,115	25,687,541	41,207,272
60° F.	1	4,295	1,587,333	33,011,111	326,500,000	962,785,714
	2	39,082	4,461,111	99,120,000	633,375,000	1,355,650,000
	3	136,533	24,673,571	639,884,615	2,407,083,333	5,346,666,666
SECTION 2.						
40° F.	1	4,295	4,138	4,566	8,247	19,693
50° F.		4,295	13,961	127,727	5,725,277	39,490,625
60° F.		4,295	1,587,333	33,011,111	326,500,000	962,785,714
40° F.	2	39,082	88,028	121,864	186,245	1,056,922
50° F.		39,082	177,437	831,615	1,731,875	13,097,166
60° F.		39,082	4,461,111	99,120,000	633,375,000	1,355,650,000
40° F.	3	136,533	281,646	538,775	749,030	852,835
50° F.		136,533	1,170,546	13,662,115	25,687,541	41,207,272
60° F.		136,533	24,673,571	639,884,615	2,407,083,333	5,346,666,666

RATIO OF GROWTH.

40° F.	1	1	1.25	1.21	2.66	5.10
	2	1	2.40	3.80	4.40	22.10
	3	1	2.47	4.62	10.19	11.99
50° F.	1	1	3.34	31.07	1,464.70	9,629.60
	2	1	6.70	24.30	86.00	612.30
	3	1	14.68	137.94	498.06	1,385.06
60° F.	1	1	398.60	8,772.10	79,809.50	288,231.80
	2	1	351.00	6,114.80	24,990.10	73,920.80
	3	1	759.90	25,308.00	61,527.20	160,873.60
40° F.	1	1	1.25	1.21	2.66	5.10
50° F.		1	3.34	31.07	1,464.70	9,629.60
60° F.		1	398.60	8,772.10	79,809.50	288,231.80
40° F.	2	1	2.40	3.80	4.40	22.10
50° F.		1	6.70	24.30	86.00	612.30
60° F.		1	351.00	6,114.80	24,990.10	73,920.80
40° F.	3	1	2.47	4.62	10.19	11.99
50° F.		1	14.68	137.94	498.06	1,385.06
60° F.		1	759.90	25,308.00	61,527.20	160,873.60

The effect of low temperature on the bacterial growth in any one of the grades of milk demands special attention. From section 2 of Table 26, it is evident that even if milk when fresh shows a low bacterial count the number of bacteria will be high if it is held at a high temperature. For example, milk with an average count of approximately 4,000 when held 24 hours at 4.4° C. (40° F.) showed approximately the same count. At 10° C. (50° F.) the count was about 13,000, while at 15.5° C. (60° F.) the average was about 1,500,000. The results show in every case the great value of holding milk at 10° C. (50° F.) rather than 15.5° C. (60° F.)

It is realized that night's milk is generally held on the farm for periods of from 12 to 15 hours before delivery; it is, therefore, important to know what bacterial increase will occur in milk held about that period of time. In order to obtain data on the subject, samples of milk produced under clean conditions in sterilized utensils and also

samples of milk produced under dirty conditions were held at 15.5° C. (60° F.) and 21.1° C. (70° F.) and examined when fresh, and after 12, 24, and 48 hours.

From Table 27 it will be seen that 16 samples of milk produced under clean conditions in sterilized utensils when fresh averaged 3,243 bacteria per cubic centimeter. After 12 hours at 15.5° C. (60° F.) the average count was 4,056 and at 21.1° C. (70° F.) 19,312 bacteria per cubic centimeter. This shows an advantage of holding at the lower temperature which is more valuable when the milk is held for 24 hours, as the average count was then 123,562 when held at 15.5° C. (60° F.) and 10,006,875 when held at 21.1° C. (70° F.). After 48 hours the average count at both temperatures was high, but the milk held at 15.5° C. (60° F.) was much lower.

The samples of milk produced under dirty conditions in unsterilized utensils ranged from 10,900 to 2,210,000 when fresh and averaged 707,761 bacteria per cubic centimeter. This high initial average count increased to 3,376,961 after 12 hours at 15.5° C. (60° F.) and to 6,608,846 after 12 hours at 21.1° C. (70° F.). The counts were, of course, very high at later periods at both temperatures.

TABLE 27.—*Growth of bacteria in milk when held at 15.5° C. (60° F.) and 21.1° C. (70° F.).*

MILK PRODUCED UNDER CLEAN CONDITIONS IN STERILIZED UTENSILS.

Sample No.	Fresh.	Held at 15.5° C. (60° F.) for—			Held at 21.1° C. (70° F.) for—		
		12 hours.	24 hours.	48 hours.	12 hours.	24 hours.	48 hours.
1	1,800	2,300	48,000	13,200,000	8,100	4,100,000	1,290,000,000
2	1,900	2,000	56,000	16,500,000	23,100	26,200,000	860,000,000
3	1,700	1,100	55,000	38,000,000	13,600	23,700,000	2,410,000,000
4	3,100	1,800	54,000	.....	29,100	12,400,000	.....
5	11,200	7,300	83,000	41,000,000	14,700	4,700,000	1,340,000,000
6	7,900	8,700	51,000	57,000,000	37,000	8,200,000	1,810,000,000
7	1,800	2,100	78,000	12,900,000	2,300	510,000	81,000,000
8	700	1,700	28,000	4,800,000	6,800	1,880,000	82,000,000
9	5,600	1,900	23,000	20,100,000	25,200	5,400,000	2,980,000,000
10	1,100	3,100	74,000	42,000,000	19,500	30,600,000	128,000,000
11	3,400	5,100	38,000	14,100,000	13,200	10,200,000	960,000,000
12	1,400	18,300	810,000	.....	58,000	5,700,000	.....
13	3,100	2,200	60,000	18,100,000	4,100	4,100,000	1,390,000,000
14	1,200	2,000	261,000	46,000,000	32,500	4,920,000	6,400,000,000
15	3,800	3,000	112,000	16,600,000	5,800	6,000,000	6,460,000,000
16	2,200	2,300	146,000	.....	16,000	11,500,000	.....
Average.	3,243	4,056	123,562	26,176,923	19,312	10,006,875	2,014,692,307

MILK PRODUCED UNDER DIRTY CONDITIONS IN UNSTERILIZED UTENSILS.

1	10,900	15,500	182,000	.....	58,000	49,000,000	.....
2	1,520,000	8,600,000	148,000,000	169,000,000	12,800,000	460,000,000	1,780,000,000
3	1,880,000	8,700,000	154,000,000	840,000,000	17,600,000	960,000,000	7,500,000,000
4	1,030,000	5,400,000	22,900,000	1,180,000,000	8,200,000	630,000,000	460,000,000
5	2,210,000	11,700,000	81,000,000	28,000,000	13,700,000	149,000,000	620,000,000
6	1,810,000	1,930,000	68,000,000	164,000,000	6,100,000	75,000,000	540,000,000
7	330,000	4,200,000	10,300,000	113,000,000	10,200,000	37,000,000	1,860,000,000
8	159,000	1,210,000	22,600,000	110,000,000	2,830,000	.....	350,000,000
9	96,000	1,310,000	29,400,000	.....	10,400,000	114,000,000	.....
10	37,000	560,0000	43,800,000	212,000,000	2,360,000	26,000,000	1,840,000,000
11	18,000	180,000	47,200,000	100,000,000	1,370,000	96,000,000	1,500,000,000
12	12,000	24,000	1,480,000	45,000,000	99,000	32,000,000	2,080,000,000
13	28,000	71,000	2,300,000	.....	198,000	35,000,000	.....
Average.	707,761	3,376,961	48,550,923	296,100,000	6,608,846	221,916,666	1,853,000,000

The ratio of growth of bacteria in Table 28 shows an interesting point. The ratios were determined as previously explained in this publication (p. 46). It will be noted that there was a higher ratio of growth in milk produced under dirty conditions in unsterilized utensils than in samples of milk produced under clean conditions in sterilized utensils. This seemed to be true when milk was held at 15.5° C. (60° F.) for 12 and 24 hours. At 21.1° C. (70° F.) the statement holds true only for the first 12 hours. From that and other observations it seems evident that the bacteria which are introduced from unsterilized utensils grow faster at temperatures near 15.5° C. (60° F.) than those in a low-count milk produced in sterilized utensils.

The results obtained by holding milk at 15.5° C. (60° F.) and 21.1° C. (70° F.) for various periods of time, show the advantage of the lower temperature and further give data on the bacterial increase which will take place at those temperatures when both low and high count milk are held for varying periods of time.

The effect of temperature on the growth of bacteria in milk during storage and transportation is a matter of very great importance. It is evident from the previous results that if a low-count milk is desired it must be cooled and held at 10° C. (50° F.) or lower on the farm, unless it is delivered immediately after each milking. Therefore, for the production, in a broad sense of the term, of milk of low bacterial content a fourth factor, proper refrigeration, must be added to the three factors previously discussed.

TABLE 28.—*Ratio of growth of bacteria in milk when held at 15.5° C. (60° F.) and 21.1° C. (70° F.).*

MILK PRODUCED UNDER CLEAN CONDITIONS IN STERILIZED UTENSILS.

Sample No.	Fresh.	Held at 15.5° C. (60° F.) for—			Held at 21.1° C. (70° F.) for—		
		12 hours.	24 hours.	48 hours.	12 hours.	24 hours.	48 hours.
1	1	1.27	26.6	7,333.3	4.5	2,277.7	716,666.6
2	1	1.05	29.4	8,684 2	12.1	13,789.4	452,631.5
3	1	0	32.3	22,352.9	8	13,941.1	1,417,647
4	1	0	17.4	.....	9.3	4,000	.....
5	1	0	7.4	36,607.1	1.3	419.6	119,642.8
6	1	1.07	6.4	7,215.1	4.6	1,037.9	229,113.9
7	1	1.16	43.3	7,166.6	1.2	283.3	45,000
8	1	2.43	40	6,428.5	9.7	2,685.7	115,714.2
9	1	0	4.1	3,589.2	4.5	964.2	532,142.8
10	1	2.81	67.2	38,181.8	17.7	27,818.1	116,363.6
11	1	1.50	11.1	4,147	3.8	3,000	282,352.9
12	1	13.07	578.5	.....	41.4	4,071.4	.....
13	1	0	19.3	5,838.7	1.3	1,322.5	448,387
14	1	1.66	217.5	38,333.3	27.1	4,100	533,333.3
15	1	0	29.4	4,368.4	1.5	1,578.9	1,700,000
16	1	1.04	66.3	.....	7.2	5,227.2	.....
Average	.....	1.69	74.76	14,634.3	9.7	5,407.3	885,307.3

TABLE 28.—*Ratio of growth of bacteria in milk when held at 15.5° C. (60° F.) and 21.1° C. (70° F.)*—Continued.

MILK PRODUCED UNDER DIRTY CONDITIONS IN UNSTERILIZED UTENSILS.

1	1	1.4	16.6	.....	5.3	4,495.4	.....
2	1	5.6	97.3	1,111.8	8.4	302.6	11,710.5
3	1	4.5	81.9	446.8	9.3	510.6	3,989.3
4	1	4.9	21	1,082.5	7.5	577.9	422
5	1	5.3	36.6	12.6	6.2	67.4	280.5
6	1	1	37.5	90.6	3.4	41.4	298.3
7	1	1.2	31.2	342.4	30.9	112.1	5,636.3
8	1	7.6	142.1	691.8	17.7	.....	2,201.2
9	1	13.6	136.4	.....	108.3	1,187.5	.....
10	1	15.1	1,183.7	5,729.7	63.7	702.7	49,729.7
11	1	10	2,622.2	5,555.5	76.1	5,333.3	83,333.3
12	1	2	123.3	3,750	8.2	2,666.6	173,333.3
13	1	2.5	82.1	.....	7.1	1,250	.....
Average	.....	5.7	354.7	1,881.3	27	1,437.3	33,093.4

SUMMARY.

1. Milk of low bacterial content and practically free from visible dirt, when fresh, was produced in an experimental barn under conditions similar to those on the average low-grade farm.

2. Three simple factors were necessary for the production of milk with a low bacterial content, namely, sterilized utensils, clean cows with clean udders and teats, and the small-top pail. A fourth factor, holding the milk at a temperature near 10° C. (50° F.) or lower, is necessary in order to keep the bacterial content low.

3. The average count of 65 samples of fresh milk produced by the aid of the three factors, except that the udders and teats were not washed, was 4,524 bacteria per cubic centimeter. The average count of milk directly from the udder was 757 bacteria per cubic centimeter; the difference of 3,767 therefore represents the number introduced through external contamination. During the same period when the udder and teats of the cows were washed, the average of the 65 samples was 2,154 bacteria per cubic centimeter, and as the average udder count was 739, the difference, 1,415 bacteria, represented those added through external contamination.

Washing the udder and teats of the cows not only caused a decrease in the bacterial content of the milk but also more nearly uniform counts.

A study of the bacterial groups in the low-count milk showed that they correspond closely to those in the milk drawn directly from the udder.

4. A practical demonstration of the value of the three essential factors was made on six farms. The results indicate that it is possible for the average farmer with inexpensive equipment to produce milk of low bacterial content with little extra work.

5. The results indicate that in general the greatest contamination of milk comes from the use of unsterilized utensils. The simple steam

sterilizer described in Farmers' Bulletin 748[1] was used very successfully for the sterilization of utensils on the farms.

6. Small-top pails were found to lessen the quantity of manure which may gain entrance into milk and to assist in lowering the bacterial count.

7. The sediment test was found to bear a somewhat close relation to the number of bacteria in fresh, unstrained milk handled in sterilized utensils.

8. From an examination of a large number of samples of fresh milk produced under varying conditions in an experimental barn and of samples from a number of farms, it is believed that as a general rule the bacterial content is relatively low. It would seem that when the count is in the millions it is the result of bacterial growth in the milk while being held.

9. To show the growth of bacteria in milk held at various temperatures for varying periods, a large number of samples were held at 4.4°, 10°, 15.5°, and 21.1° C. (40°, 50°, 60°, and 70° F.). It is absolutely necessary, if milk is held on the farm, to keep it near 10° C. (50° F.) or lower, in order to restrain bacterial growth, if the dairyman wishes to market milk of low bacterial content.

CONCLUSIONS.

The results of the experiments indicate that it is possible for the average dairyman on the average farm, without expensive barns and equipment, to produce milk (practically free from visible dirt) which when fresh has a low bacterial count. By the use of the three simple factors, namely, sterilized utensils, clean cows with clean udders and teats, and the small-top pail, it should be possible on the average farm to produce milk which corresponds closely to milk as it leaves the udder of the cow. A fourth factor of holding milk at as near 10° C. (50° F.) as possible is also absolutely necessary.

To emphasize the value of the three simple factors, figure 23 shows the average bacterial counts of milk produced under the various conditions described in this bulletin. The results will not be discussed in detail, but in a general way the figure gives a picture of the results of the experiments in the order in which they were conducted. The experiments were begun with dirty conditions and unsterilized utensils, and milk of high bacterial count was obtained. Next the factor of sterilized utensils was introduced, followed by the additional factor of clean udder and teats. A combination of the factors and the use of a small-top pail permitted the production of a low-count milk, which closely corresponded to that drawn directly from the udder. In order to check the value of the essential factors, they were again eliminated until a high-count milk was produced, then reintroduced until a low-count milk was again obtained.

[1] Farmers' Bulletin 748 will be sent free to any one on application to the department.

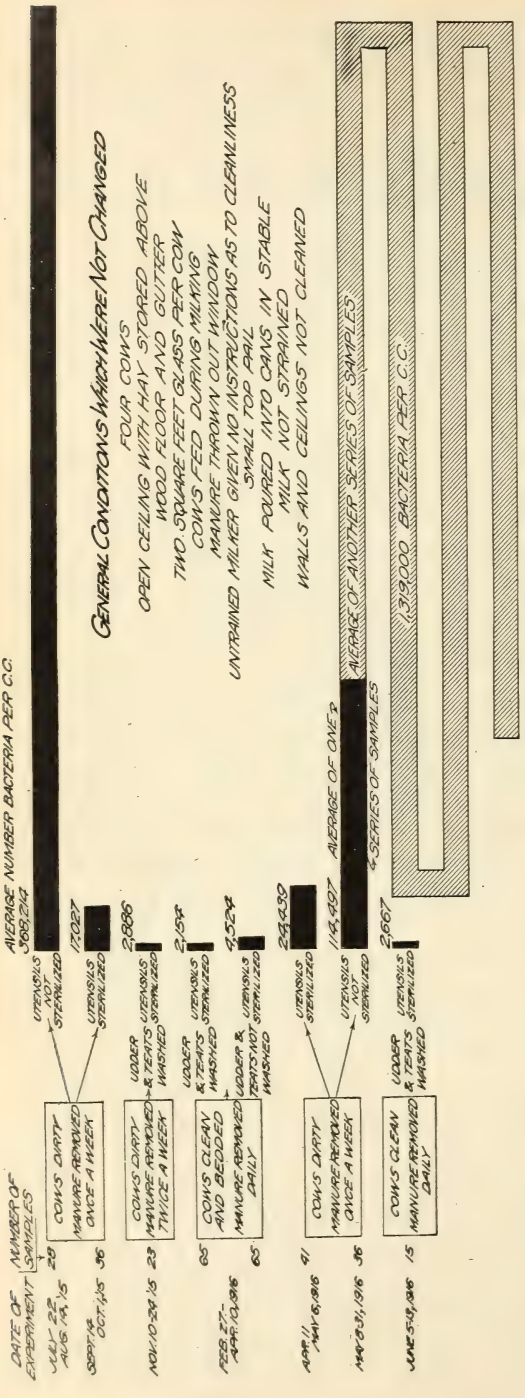


Fig. 23.—Summary of results showing the average bacterial content of milk produced under the various conditions described in this paper.

The value of these factors was thoroughly determined by experiments conducted in an experimental barn and further demonstrated by their successful practical application on several farms.

In connection with the production of milk of low bacterial content and which is practically free from visible dirt, it seems evident from the results that undue emphasis has been given to factors and methods of minor importance, while those which directly affect the bacterial content have not been sufficiently emphasized.

It must again be pointed out that only one phase of the production of a sanitary milk has been considered in this paper. No attempt has been made to study the factors which are most directly concerned with preventing the infection of milk by pathogenic organisms. The factors affecting the health of the cattle have not

been studied, nor has the influence of general conditions of cleanliness surrounding the production of milk been given consideration.

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